6.0 Benthos

6.1 Introduction

Benthic macroinvertebrates are animals living at least part of their life cycle upon or within the available substrate (e.g., bottom sediments, debris, vascular plants, filamentous algae, etc.) in an aquatic environment. Benthic organisms are less mobile than fish and require relatively longer periods to complete the aquatic portion of their life cycle than plankton. Since benthic organisms exhibit limited mobility and relatively long life cycles, they are often slow to recolonize areas subjected to severe environmental perturbations. The specific types and number of benthic organisms present at a site tend to reflect extreme rather than average environmental conditions which have occurred in the recent past. This reflection of extremes enables the benthos to act as detectors of even occasional severe environmental changes. (Garton and Harkins, 1970; Weber, 1973)

The major taxonomic groups comprising a freshwater benthic community may include flatworms, roundworms, annelids, molluscs, crustaceans, and insects. Such a taxonomically diverse benthic community would contain organisms participating in the aquatic food web at several trophic levels (i.e., some groups of benthic organisms are considered herbivores, other omnivores, while still others are carnivores) (Weber, 1973). Assuming organisms in one trophic level may be more sensitive to a particular adverse environmental condition than organisms in some other trophic level, an analysis of the physical "well-being" of the benthic community may yield valuable information concerning the suitability of an area for organisms occupying various levels of the trophic structure.

The purpose of this investigation was (1) to establish spatial and temporal distribution of selected groups of organisms, and (2) to evaluate the effects of the H. B. Robinson Steam Electric Plant effluent on selected portions of the benthic community.

The effects of thermal effluent on benthic communities have not been studied extensively at this time. Many of the studies conducted to date have dealt with rivers rather than lakes, or with lakes receiving organic enrichment, or heavy siltation, etc. in addition to thermal effluent (Weiss et al., 1974).

Since the effects of thermal effluents on systems not complicated by other factors appear to be largely unknown, a comparison of Robinson Impoundment with similar black-water reservoirs is difficult.

Studies on the effects of thermal effluents include a study by Lenat and Weiss (1973) on Lake Wylie located in portions of North and South Carolina. They reported that in the area of thermal discharge the number of littoral organism groups (i.e., taxa) exhibiting population density increases was approximately equal to the number of groups exhibiting population decreases. Thermal effluents also influenced the standing crop of several groups of organisms living in the sublittoral portions of the lake.

From a study conducted on Lake Hyco, North Carolina, Weiss et al. (1974) reported that thermal effects on the littoral benthic community included depression of organism standing crop and diversity in the discharge pool and at a nearby lake station receiving the warm water plume.

As temperature rises above 4°C, water decreases in density. This decrease enables heated effluents to "float" over the colder water usually associated with increased depth. The greatest increases over ambient temperatures, therefore, may occur in the shallower portions of a lake. Benthic organisms inhabiting these shallow areas are often subjected to naturally occurring severe daily and seasonal temperature fluctuations. If benthic organisms in shallow areas can survive these natural fluctuations, the effect of thermal discharge may not be as great as might be expected (Lenat and Weiss, 1973).

Without the benefit of pre-operational benthic data, it was not possible to determine if the observations made during this study adequately reflect the relative numerical abundance, spatial distribution, or species composition of organisms present prior to plant operations. This study may indicate the possible effects of plant effluent on the spatial and temporal distributions of selected benthic macroinvertebrate groups during the recent past.

6.2 Methods

Selected portions of Robinson Impoundment benthic community were sampled monthly from January 1975 through December 1975. This sampling program included collection of three replicate samples at each of two station located on each transect. Six transects were established at intervals along the length of the lake using preimpoundment topographic maps (Figure 3.1.1).

Station locations illustrated in Figure 3.1.1 correspond to benthic sampling stations with the following exceptions: (1) benthic sampling station A-3 was located approximately 50 to 75 meters west of temperature sampling Station A-2, (2) benthic sampling Stations E-1, F-S, and G-S were located in littoral areas east of thermal sampling Stations E-1, F, and G respectively.

Benthic samples were collected with a Petite Ponar Grab which samples an area 15.2 cm x 15.2 cm (6 in x 6 in) and a volume, under optimal conditions, of 2.46 1 (150 in^3). Samples were washed on station using a U. S. Standard No. 30 mesh sieve. The sample residue was immediately placed in a plastic container and preserved with 10% formalin solution containing biological stain. In the laboratory each sample was hand sorted; benthic organisms were removed, preserved in 70% ethyl alcohol, and stored to await enumeration and identification. Numbers of organisms were recorded to the lowest practical taxon with the aid of suitable taxonomic references (Ross, 1944; Edmondson, 1944; Parrish, 1968; Klemm, 1972; Brown, 1972; Mason, 1973). The identification of larval Chironomidae required the use of a compound scope and the mounting of organisms using CMC-9 (Master's Chemical Company, 2504 South Harvey Ave., Berwyn, Illinois 60402).

The substrate contained in each benthic grab was subjectively characterized according to content as either silt-detritus or sand-detritus. This subjective description of substrate type as well as the depth of water overlying the substrate were recorded for each benthic grab.

Additional monthly macroinvertebrate collections were made in portions of Black Creek above and below Robinson Impoundment (Stations H, K, and I) and in shallow areas of the impoundment adjacent to Transects E, F, and G using slightly modified multiplate samplers similar to the sampler described by Fullmer (1971). Three samplers were placed at each station with the first sampler suspended at a depth of 0.3 m (0.98 ft) below the surface of the water, the second at the 0.6 m (1.97 ft depth and the third at 0.9 m (2.95 ft). Samplers were set out at each station for approximately one month to allow sufficient time for colonization. Afterwards, the samplers were removed individually with special care being taken to collect all organisms. Benthic macroinvertebrates were removed, preserved, and returned to the laboratory for analysis. Samplers were returned to the water.

Analysis of benthic organisms following identification included computation of mean diversity ($\bar{d}$) using the machine formula presented by Lloyd, Zar, and Karr (1968).

Although the initial study design for this 316 demonstration included determination of benthic biomass estimates of selected taxa collected in the Robinson Impoundment, these estimates could not be made for the following reasons:

1. Dominant taxa were not collected in sufficient numbers from each station to allow the determination of monthly biomass estimates.

2. Organisms representing many of the dominant taxa were mounted prior to identification, thus they were unavailable for biomass estimates.

6.3 Results and Discussion

Although many factors may cause the horizontal variation in the occurrence of benthic macroinvertebrates in Robinson Impoundment, some of the more obvious include substrate, depth, and temperature. In an attempt to reduce the inter-station variation in organism abundance due to differences in either substrate or depth, stations were grouped according to depth and substrate similarities. The following four groups of stations were established and designated as groups I, II, III, and IV.

Group	Station	Depth At Station	Substrate
I	A-1	3 m	sand-detritus
	C-1	3 m	sand-detritus
	E-3	2 m	sand-detritus
II	A-3	10 m	sand-detritus
	C-3	9 m	silt-detritus
	D-1	6 m	silt-detritus
III	D-3	2 m	silt-detritus
	F	3 m	silt-detritus
	G	2.5 m	silt-detritus
IV	E-1	1 m	sand-detritus
	F-S	1 m	sand-detritus
	G-S	1 m	sand-detritus

Since substrates sampled at Station A-3 appeared to contain more sand than substrates collected at Stations C-3 and D-1, the three stations are considered loosely grouped according to depth.

Species Composition

During the one-year study presented in this report, 135 taxa of benthic macroinvertebrates were collected in Robinson Impoundment and portions of Black Creek. The major taxonomic groups, presented in order of decreasing numbers of taxa, include Diptera (60 taxa), Trichoptera (15 taxa), Odonata (12 taxa), Ephemeroptera (10 taxa), Plecoptera (10 taxa), Coleoptera (9 taxa), Annelida (9 taxa), Amphipoda (3 taxa), Lepidoptera (2 taxa), Turbellaria (1 taxon), Nematoda (1 taxon), Hydracarina (1 taxon), Collembola (1 taxon), and Megaloptera (1 taxon). A complete list of taxa is presented in Table 6.3.5. This table also indicates taxa collected at Black Creek Stations H, K, and I.

Groups of organisms represented in this list were collected using one or both sampling methods described above. The two types of samplers collect qualitatively and quantitatively different faunal samples (Weber, 1973). The observed qualitative differences in faunal samples can be summarized as follows: (1) Petite Ponar samples contained organisms representing 26 taxa which were not collected by substrate samples, (2) substrate samples contained 44 taxa which were not present in ponar samples, and (3) the total number of taxa (91) collected from ponar grabs was less than the total number (109) collected from multiple plate samplers. These differences indicate each of the two samplers collected organisms from slightly different portions of the benthic community present in the study area. The data obtained using ponar grabs, therefore, cannot be easily compared with data obtained from substrate samplers. Since a comparsion will not be attempted, data obtained from grab samplers will be presented in the impoundment portion of this report while data collected from multiplate samplers located at Stations H, I, and K will be presented in the Black Creek section.

The number of taxa collected in a lake study is influenced by the number and type of microhabitats sampled, by the frequency and intensity of sample collection, and by the type of sampler used. It is difficult, therefore, to accurately compare the qualitative and quantitative aspects of total numbers of taxa collected from the Robinson Impoundment with numbers presented in other studies.

6.3.3 Numerically Dominant Organisms

Although a relatively large number of taxa were collected throughout the study period, only a few groups of organisms could be considered numerically important. Arbitrarily defining a numerically important group as one containing >5% of the total organisms, the important taxa include Chironomidae (41% of the total), Oligochaeta (33%), and Culicidae (12%). Combined, these three taxa made up 86% of the total number of organisms collected. Organisms representing taxa not mentioned above were collected in relatively low numbers and were considered uncommon. With the exception of a few genera of Trichoptera and Ephemeroptera, considered important fish food organisms, the spatial and temporal distributions of uncommon taxa were not determined from this study.

Chironomidae

Organisms representing 36 genera of Chironomidae (midges) were taken from ponar samples. The numbers of genera collected in each subfamily include 18 genera of Chironominae, nine Orthocladiinae, and eight Tanypodinae. Chironomus (Chironominae) was the dominant midge representing 7.6 percent of the total number of Chironomidae collected.

The numerical dominance of Chironomus has been reported from other studies. For example, Weiss et al. (1974) reports Chironomus is a common dominant in shallow or eutrophic lakes, especially those with thermocline formation. According to Hilsenhoff and Narf (1968), Chironomus is the most common benthic organism in 14 Wisconsin lakes which have maximum depths of 20-32 feet, relatively large profundal zones, and soft sediments. Although the total number of organisms representing Chironomus indicate it was the numerically dominant midge collected in Robinson Impoundment, this dominance was effectively restricted to the three relatively deep Stations A-3, C-3, and D-1. Figure 6.3.1 illustrates the observed spatial distribution of Chironomus expressed as monthly mean number of organisms per meter^2 collected at each station. Numbers of organisms ranged from a high of 579/m^2 at Station C-3 to a low of 82/m^2 at Station D-1, while at Station A-3 an intermediate value of 222/m^2 was observed. Numbers of organisms collected at the remaining nine stations were comparatively low, ranging from 61/m^2 at Station A-1 to 2/m^2 at Station G.

The abundance presented above clearly indicate that Chironomus preferred the deeper stations. Depth preferences have been reported in published studies including one conducted on Lake Washington by Thut (1969). He reported that numbers of fourth instar Chironomus sp. (nr. ferrugenoerittatus) gradually increased in abundance with increasing depth, finally reaching an abundance peak at 50 meters (16.5 ft). He also observed a peak in the numerical abundance of Chironomus plumosus at 10 meters (33 ft), while at greater depths abundance steadily decreased. A depth preference may explain the relatively higher numbers of organisms collected at Robinson Impoundment Stations A-3, C-3, and D-1 and the lower numbers collected at the remaining nine benthic stations.

Other environmental factors appear to influence the depth distribution of Chironomus. The influence of these factors was apparent from a comparison of the relative numerical abundance of Chironomus at stations of similar depth. For example, the depth at Station A-1 was comparable to depth at Station C-1, yet monthly mean numbers collected were not similar at these two stations (Figure 6.3.1). This station to station variability may be related to a depth preference coupled with various inter-station changes in environmental factors (e.g. availability of suitable food, microhabitat, temperature or dissolved oxygen concentrations). It is unclear from this study which factor or combination of factors influenced inter-station change in the numerical abundance of Chironomus.

The number of generations per year of Chironomus was not clearly evident from the data collected. A reasonable estimate, however, is one generation per year with an abundance peak in the fall and winter, and decreasing numbers in the spring and summer.

Since relatively large numbers of Chironomus preferred the deeper cooler stations and reached their peak abundance during the colder seasons, it appears that thermal effluents from the H. B. Robinson Plant did not adversely effect the numerical abundance of Chironomus.

In the subfamily Chironominae, other organisms considered common or frequently collected represented the genera Polypedilum (2.4% of the total number of larval chironomids), Cladotanytarsus (2.2%), Cryptochironomus (0.8%), and Harnischia (0.8%). These midges will be discussed in order of numerical abundance.

The results of two studies, one conducted on Lake Wylie by Lenat and Weiss (1973), the other on Belews Lake by Weiss et al. (1974), indicate Polypedilum is a common littoral organism which may favor areas containing organic enrichment. According to Lenat and Weiss, this preference for enriched areas, rather than temperatures, may control the occurrence of Polypedilum.

The spatial distribution of Polypedilum in Robinson Impoundment is demonstrated in Figure 6.3.2, which presents the monthly mean number of Polypedilum/m^2 collected at each of the 12 stations. These data indicate higher numbers of organisms were collected at Stations F-S, G-S, C-1, and A-1 (corresponding no/m^2 were 72, 65, 53, and 44, respectively), lower numbers at Stations A-3 (1/m^2), C-3 (none observed), and D-1 (1/m^2) and intermediate values at Stations D-3 (16/m^2), E-1 (23/m^2), E-3 (16/m^2), F (11/m^2), and G (18/m^2). These data indicate that Polypedilum were relatively common at all stations where depth was less than 5 meters (16.5 ft.) and uncommon at the deeper stations. This depth distribution agrees, in part, with the above mentioned published literature.

The spatial distribution of Polypeidlum presented in Figure 6.3.2 clearly indicates that comparable numbers of organisms were collected at several stations previously grouped as having similar substrate and depth. The monthly mean number collected at Station D-1 was comparable, for example, to the numbers collected at Station F and G (Group III). A second group of stations having similar depth and substrate include A-1, C-1, and E-3 (Group I). The monthly mean number of Polypedilum collected at Station A-1 was similar to the number collected at Station C-1; however, abundance was reduced by one-half at Station E-3. Stations E-1, F-S, and G-S (Group IV) were also grouped according to depth and substrate similarities. A comparison of the mean numbers of Polypedilum collected at these three stations indicated abundance was similar at Stations F-S and G-S while the number of organisms collected at Station E-1 were decreased threefold. With the exception of the relatively low numbers of organisms collected at Stations E-1 and E-3, comparable numbers of organisms were collected at all stations grouped as offering similar depths and substrates. Although naturally occurring environmental factors may be responsible for the depressed organism abundance observed at Station E-1 and E-3, this study did not eliminate the possibility that depressed organism abundance was due to a low tolerance to the effects of heated effluents.

Other members of the subfamily Chirononimae include Cladotanytarsus, Harnischia, and Cryptochironomus. The spatial distribution of organisms representing each taxon is presented in Table 6.3.2 as the monthly mean number of organisms/m^2 collected at each of the twelve benthic sampling stations.

The observed spatial distribution of Cladotanytarsus indicated organisms were either collected in relatively low numbers or were not encountered at the three relatively deep stations (i.e., A-3, C-3, and D-1). These data appear to indicate that Cladotanytarsus preferred the shallower areas of the impoundment. The spatial distribution of Cladotanytarsus also indicated organisms were encountered at all benthic sampling stations with the exception of the deeper stations mentioned above and Station E-1 and E-3 which are located in the discharge area. The absence of Cladotanytarsus in the discharge area may be related to elevated water temperatures (Section 3.3.2) or other environmental factors not apparent from this study.

The data presented in Table 6.3.2 indicate organisms representing Harnischia were collected in relatively higher numbers at Stations D-1, F, F-S, G, and G-S and in lower numbers at the remaining benthic sampling stations. It was not clear from this study what environmental factors influenced the observed station to station variation in organism abundance.

Cryptochironomus was collected in relatively low number (1 organism/m^2) at Stations A-3, C-3, D-1, and D-3 while at the remaining stations numbers of organisms ranged from 5 organisms/m^2 at Station F-S to 26 organisms/m^2 at Station A-1. These data (Table 6.3.2) do not clearly indicate if organism abundance is depressed at the mid-impoundment stations.

Tanypodinae

The Tanypodinae collected in Robinson Impoundment included Procladius, Ablabesmyia, and Clinotanypus.

Groups of organisms representing Procladius (3.5% of total number of midges collected) and Ablabesmyia (3.0% of midges collected) were considered common in benthic sampling while Clinotanypus (<1% of the midges collected) was frequently encountered.

Two morphologically different forms of Procladius were collected in Robinson Impoundment. These forms will be represented as Procladius (aberrant) and Procladius. The spatial distribution of organisms representing each form was determined to illustrate changes in abundance throughout the impoundment (Table 6.3.3).

The group of organisms representing Procladius (aberrant) included 22% of all Procladius collected. Procladius (aberrant) was encountered in collections from all twelve benthic stations except Station D-3. Numbers ranged from a high of $138/m^2$ at Station E-1 to $1/m^2$ at Station A-3. Highest numbers were collected at the shallower stations (depth less than 1 meter), lower numbers at the deeper stations (depth greater than 5 meters), and intermediate numbers at the remaining stations (Table 6.3.3).

The spatial distribution observed for Procladius (aberrant) indicates an apparent preference for littoral areas. This preference is illustrated by a peak in the numerical abundance at Stations E-1 and F-S. The relatively lower numbers of organisms collected at the third littoral station (G-S) cannot be adequately explained from the data collected. The study appears to indicate, however, that heated effluent did not adversely influence organism abundance at any of the littoral stations.

The spatial distribution of organisms representing the second morphological form of Procladius is illustrated in Table 6.3.3. These data indicate Procladius were present in collections from all benthic sampling stations. The monthly mean number of Procladius ranged from a high of $265/m^2$ at Station G to a low of $34/m^2$ at Station E-1. The data also indicate relatively higher numbers of Procladius were collected at stations located in the lower and upper impoundment stations. In an attempt to limit the number of environmental factors other than temperature which might influence the observed inter-station variation in organism abundance, only stations with similar depths and substrates were compared for variations in numerical abundance. As mentioned above substrate and depth were similar at Stations A-1, C-1, and E-3. The monthly mean number of organisms collected at each of the two lower impoundment stations was greater than the mean number of organisms collected at Station E-3. Substrates and depth also appeared comparable at Stations G-S, F-S, E-1. The monthly mean number of *Procladius* collected at Stations G-S and F-S ($114/m^2$ and $75/m^2$, respectively) was two-fold higher than the number collected at Station E-1 ($34/m^2$). The numerical abundance of *Procladius* collected at Stations D-3, F, and G ranged from a low of $89/m^2$ at Station D-3 to a high of $265/m^2$ at Station G. Numerical abundance at the remaining group of stations (Group II) ranged from $230/m^2$ at Station C-3 to $134/m^2$ at Station A-3. It is apparent from the above comparisons that the numerical abundance of *Procladius* was reduced at Stations E-1 and E-3 when compared to the abundance at other benthic sampling stations.

A similar reduction in abundance has been observed at Lake Hyco, North Carolina (Weiss et al., 1974). Weiss reported all dominant Chironomidae were depressed by thermal effects with *Procladius adumbratus* depressed mainly in the discharge area. Although it appears likely that the depressed abundance of *Procladius* at the discharge stations of Robinson Impoundment reflects adverse effects of thermal effluents, it is possible that other factors not apparent from this study influenced the abundance of *Procladius* at Stations E-1 and E-3.

Organisms representing *Ablabesymia* were collected from all twelve benthic sampling stations. Greater numbers of organisms were collected from the relatively shallow stations (depth less than 5 meters) and fewer organisms at the deeper Stations A-3, C-3, and D-1 (Figure 6.3.3). Abundance ranged from a high of $114/m^2$ at Station G-1 to a low of $2/m^2$ at Stations C-3 and D-1. It was not apparent from this study what environmental factor or combination of factors influenced the observed spatial distribution. It was also unclear what effect plant effluent had on the abundance of organisms collected throughout the impoundment.

The spatial distribution of organisms representing *Clinotanypus* is illustrated in Table 6.3.4. It is apparent from these data that *Clinotanypus* was collected in greater numbers at the relatively shallow Stations F-S and G-S, with 39 and 26 organisms/m^2, respectively, thus indicating a possible preference for littoral areas. Organism abundance decreased at Stations A-1, C-1, D-1, E-3, E-1, F, and G, and ranged from a high of 6 organisms/m^2 to a low of 1/m^2, while Clinotanypus was not encountered in collections from Stations A-3, C-3, and D-3. Since Clinotanypus appears to be a littoral organism, a comparison of sublittoral inter-station variation in organism abundance will not be included. A comparison of inter-station variation, therefore, will be restricted to Stations G-S, F-S, and E-1 which were located in littoral areas. The decreased abundance of Clinotanypus at Station E-1 (5 organisms/m^2) possibly indicates this group of organisms was adversely effected by thermal effluents, however, other environmental factors not apparent from this study may have influenced the numerical abundance of Clinotanypus.

Oligochaetes

Oligochaetes (worms) were collected at all twelve benthic sampling stations throughout the year (Table 6.3.5). The monthly mean number of worms collected ranged from a high of 818/m^2 at Station A-3 to a low of 133/m^2 at Station E-1. For the efficient utilization of time and energy, worms were identified to class. Since the spatial and temporal distributions of organisms identified to class frequently yields little information, further discussion of Oligochaetes will not be presented.

Culicidae

Chaoborus (phantom midge) is considered an important food source for fish in the Robinson Impoundment. Chaoborus larvae are, according to Larow and Marzolf (1970), unique in the Class Insecta in that they exhibit a regular diel vertical migration. The first two instars (immature larvae) are planktonic, thus unavailable for collection by the benthic samplers used in the Robinson Impoundment study. The third and fourth instars (mature larvae) are planktonic at night but burrow in the bottom sediments during the day when they may be collected as "benthic" organisms. This difference between immature and mature larvae during diel vertical migration has been widely reported (Juday, 1921; Wood, 1956; Woodmansee and Grantham, 1961) in the published literature. All four instars migrate to the surface water after sunset and return to the deeper portions of the lake (immature larvae) or to the sediments (mature larvae) shortly before sunrise. The daily vertical migration of larval Chaoborus may expose both immature and mature organisms to the effects of thermal effluents which "float" over ambient water and to loss due to plant entrainment (Weiss et al., 1974).

Organisms representing larval Chaoborus comprised 12.7% of the total number of organisms collected. Figure 6.3.4 illustrates the monthly mean number of larval Chaoborus/meter^2 collected at each benthic sampling station. These data indicated that phantom midges either were not observed or were not collected in relatively low numbers at the shallow Stations E-1 (Chaoborus not observed), F-S (2/m^2), and G-S (8/m^2). At stations of intermediate depth, numbers of organisms collected ranged from 29/m^2 at Station C-1 to 128/m^2 at Station F. Relatively higher numbers of Chaoborus were collected at the deeper Stations A-3, C-3, and D-1 with 224, 554, and 435/m^2, respectively.

Throughout the year Chaoborus exhibited two abundance peaks: one in July 1975, and the other in November 1975 (Figure 6.3.8). Seasonally, numbers of Chaoborus decreased from January through May, increased in June, peaked in July, then decreased again in August. Numbers of organisms began increasing in September, reached a second abundance peak in November, then decreased in December. This seasonal pattern indicates two generations per year, a relatively long winter generation occurring from September through May and a second short summer generation from June through August or September (Figure 6.3.8). The number of generations per year reported in the published literature apparently varies between lakes. Usually one generation per year is reported (Sublette, 1957; Hilsenhoff and Narf, 1968); however, Weiss et al., (1974) reported two generations per year for Chaoborus in Lake Hyco. He also reported that in both one and two generation patterns larval Chaoborus are never entirely absent at any time.

Information from the published literature indicates that the greater numbers of organisms collected from the relatively deep stations in Robinson Impoundment is to be expected. The two generation pattern per year has been reported in the literature and is not unique to the Robinson Impoundment.

A comparison of numbers of organisms collected at Station A-3 with numbers collected at Stations C-3 and D-1 indicates relatively large inter-station variation in organism abundance. The mean numbers of Chaoborus collected at Station A-3 was approximately one-half the number collected at Stations C-3 and D-1 (Figure 6.3.4). A limited entrainment study indicated 5.2×10^8 and 5.5×10^8 larval Chaoborus were lost to the plant per day during July and September, respectively. The larval Chaoborus lost during these two periods appear to be early instars of the above mentioned summer and winter generations. Although it appears likely that the numbers of organisms lost to the plant through entrainment account for the decreased abundance of larval Chaoborus at Station A-3, it is possible that other environmental factors including substrate and food availability may account for the depressed abundance observed during this study.

The depressed abundance of Chaoborus due to apparent loss by entrainment has been reported by Weiss et al. (1974) during his study of Lake Hyco. He observed a 52% reduction in the standing crop of larval Chaoborus in the vicinity of plant intake structures. This reduced abundance at Lake Hyco is similar to the depressed numbers of organisms observed at Robinson Impoundment Station A-3.

Although relatively low numbers of Chaoborus were collected at stations (Groups I, III, and IV) where depth was less than 5 meters (16.5 ft), it should be noted that Chaoborus were present in samples nine of twelve months at most stations with the exception of Station E-3 and littoral Stations E-1, F-S, G-S. Since Chaoborus are not littoral organisms, the low numbers or absence of Chaoborus at Stations E-1, F-S, and G-S is to be expected. The absence of Chaoborus at Station E-3 during portions of the year, however, appears to indicate the discharge area may not offer suitable habitat. Although many environmental factors may reduce the suitability of a habitat, it appears likely that physical scouring and/or increased water temperatures may explain the periodic absence of Chaoborus at Station E-3 during this study.

Ephemeroptera (Mayflies)

Hexagenia was considered a common mayfly in benthic samples collected in the upper portion of Robinson Impoundment. This mayfly belongs to a family (Ephemeridae) of burrowing organisms. Hexagenia is a common inhabitant of the sublittoral and profundal zones of lakes and it is reported (Eriksen, 1968) to occur in undisturbed sediments where the dissolved oxygen concentration of the water is greater than 0.8 mg/l. According to Gaufin (1973), the lethal temperature, at which 50% of his test specimens of Hexagenia lumbrata died after 96 hours exposure (TLm^{96}), was 26.6°C.

In Robinson Impoundment, Hexagenia were present in samples collected at four stations (i.e., Stations F, F-S, G, and G-S) and were not observed in samples collected at the remaining eight stations (Figure 6.3.6). The absence of Hexagenia from discharge and lower impoundment stations can not be explained from this study.

Trichoptera (caddisflies)

Two genera of caddisflies (Polycentropus and Oecetis), considered common fish food organisms, were collected in Robinson Impoundment. Organisms representing each genera were relatively more abundant in samples collected at comparatively shallow stations and less numerous or absent from samples collected at the deeper Stations A-3, C-3, and D-1. The mean monthly number of Polycentropus per meter^2 collected at each of the twelve benthic stations is illustrated in Figure 6.3.6. Data presented in this figure indicate that the number of organisms collected at most upper and lower impoundment stations, except deep Stations A-3, C-3, and D-1, was greater than numbers of organisms collected at either Station E-3 or E-1. An adequate explanation for the decreased abundance of Polycentropus at Stations E-1 and E-3 was not apparent from this study. Temporal distributions indicate, however, that immature Polycentropus were present during the summer at most stations with the exception of Stations E-1 and E-3. Adverse environmental factors including temperature may be reflected in the absence of Polycentropus from discharge stations during the warmer seasons. This absence may account for the observed decreased abundance reflected in monthly mean numbers.

The second group of caddisflies collected in the Robinson Impoundment represented Oecetis. According to Sublette (1957), Oecetis is considered unusual in that it occurs most commonly on sandy substrates. In Robinson Impoundment, Oecetis was collected in relatively high numbers at Stations D-3, E-1, E-3, F-S, and G-S where the substrate contained a comparatively high percentage of sand, while lower numbers of organisms were collected at Stations G and F where the substrate contained a relatively larger amount of silt (Figure 6.3.7). These data seem to indicate that the spatial distribution of Oecetis may be influenced, in part, by substrate differences and that plant effluents may not adversely effect organism abundance.

Species Diversity

A diversity index ($\bar{d}$) derived from information theory, is a commonly used technique for the evaluation of benthic community structure. The greater the number of species present and the more equal their abundance, the greater the uncertainty and hence the greater the diversity. Conversely, if large numbers of individuals and small numbers of taxa typify the community, then a high probability exists that an individual species observed during sampling belongs to a taxa previously observed; thus considerable replication of information would exist and diversity would be low. (Cairns and Dickson, 1971).

Environmental change which infringes upon the lethal limits for any species in a community will result in the reallocation of resources and the alternation of patterns of community stability. According to Headrich (1975) such alterations and reallocations will be reflected by changes in diversity. Environmental stress, for example, will narrow the lethal limits of the less tolerant species in a system. Organisms representing these species will be eventually reduced in abundance or eliminated from the community. This reduction or elimination will decrease local community diversity. Numerous published field studies have shown that community diversity decreases in the face of severe environmental stress (e.g., King and Ball, 1964; Wilhm and Doris, 1966; and Wilhm, 1967).

The diversity of aquatic insect populations in thermal, post-thermal and natural streams were compared by Howell and Gentry (1974). They observed that for insect communities the highest diversity indices corresponded with natural streams, intermediate diversity estimates with post-thermal streams and lowest diversity estimates with thermal streams.

Monthly diversity estimates ($\bar{d}$) for each benthic station are presented in Table 6.3.6. These data indicate that values for $\bar{d}$ varied from a high of 4.21 at Station G-S to a low of 0.00 at Station E-1 and that diversity estimates for stations located in the upper impoundment were somewhat higher than the diversity estimates for stations located either in the lower or the mid-impoundment. With some exceptions, diversity estimates for relatively shallow stations were generally higher than estimates for the deep stations. For example, values of $\bar{d}$ ranged from a low of 0.74 to a high of 2.27 for Station D-1 (a deep station), while for Station D-3 (a shallow station) the range was 1.55 to 2.99. Diversity estimates also varied seasonally with $\bar{d}$ values generally increasing in the winter and decreasing in the late spring, summer, and early fall. Seasonal variation in diversity estimates were observed for all benthic sampling stations; however, for most shallow stations values for $\bar{d}$ were greater than one throughout the study. Values for $\bar{d}$ <1 may indicate insufficient sample size or adverse environmental conditions which might include inadequate dissolved oxygen concentrations or unsuitable water temperatures. It was unclear from this study if the calculated values of $\bar{d}$ $\leq$1 reflected inadequate sample size or environmental stress. If the observed low values of $\bar{d}$ indicate environmental stress, the benthic community at Stations C-3, E-1, and E-3 may not be balanced or stable during the summer.

Black Creek

A general summary of number of taxa, number of organisms and major components of the fauna at Stations H, K, and I is given in Table 6.3.7. Station H, just below the outfall, had the fewest number of taxa and relatively highest number of organisms. The web spinning hydropsychids dominated the fauna comprising 67% of the organisms collected. The chironomids were considered common at Station H, comprising 27% of the total number of organisms collected.

One possible explanation for the high number of hydropsychids collected just below the impoundment was proposed by Spence and Hynes (1971). They stated that high numbers of web spinning trichopterans were found below an impoundment's outfall and that the high organic and detrital matter coming out of the lake supported high numbers of *Hydropschidae*.

At Station K, located downstream of Station H, the fewest numbers of organisms were collected. Of the total number of organisms collected, 55% were chironomids and 37% were trichopterans.

The number of taxa collected at Station I was two-fold higher than the number collected at Station H and 1.5 times higher than the number collected at Station K. Midges were the numerically dominant groups of organisms collected at Station I where they accounted for 69% of the total number of organisms collected.

These data indicate that the benthic community is similar at Stations I and K, while at Station H the benthos is dominated by Hydropsychids.

Summary and Conclusions

The numerically important benthic taxa collected during the study were chironomids (41% of the total), Oligochaeta (33%) and Culicidae (12%). Combined these three taxa totaled 86% of the organisms collected. Within the remaining 14% two additional taxa, Trichoptera and Ephemeroptera were examined because of their importance as fish food items. The remaining taxa were not collected in sufficient numbers to merit further consideration.

Within the numerically important taxa, spatial and temporal distributions were determined for the most frequently collected genera (Tables 6.3.2 - 6.3.6 and Figures 6.3.1 - 6.3.8).

Diversity indices were calculated to obtain information on benthic community structure and stability (Table 6.3.6).

Organism abundance and diversity appeared to be relatively consistent throughout the year at all parts of the impoundment except the discharge area. The abundance and diversity at the discharge were similar to the other sampling areas of the impoundment from November through May, but were depressed during summer months. Data suggest that this depression of diversity and abundance at the discharge is the result of the thermal effluent during the summer months.

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Table 6.3.1 Robinson Impoundment and Black Creek benthic taxa list
January - December 1975

Taxa	Organisms Collected from Black Creek	Collection Method[1]
Platyhelminthes		
Turbellaria		
Planariidae		
Dugesia	+	P.S.
Nematoda	+	P.S.
Annelida		
Oligochaeta	+	P.S.
Lumbriculidae		P
Naididae		P.S.
Tubificidae		P.S.
Peloscolex variegatus		P
Peloscolex sp.	+	P.S.
Polychaeta		
Serpulidae		
Manayunkia speciosa		P
Hirundinea		
Erpobdellidae		
Erpobdella		P.S.
Glossiphonidae		
Placobdella		P.S.
Arthropoda		
Crustacea		
Amphipoda		
Talitridae		
Hyallela azteca		P.S.
Gammaridae		
Gammarus		P
Crangonyx		S
(Arachnoidea-Hydracarina)	+	P.S.
Insecta		
Collembola	+	P.S.
Ephemeroptera		
Ephemeridae		
Hexagenia		P.S.
Caenidae		
Caenis		P.S.
Ephemerellidae		
Ephemerella	+	P.S.
Leptophlebiidae		
Leptophlebia		P.S.
Paraleptophlebia	+	P.S.
Heptageniidae		
Stenonema	+	S

P = found in Ponar sample
S = found on artificial substrate

P.S. = Collected by both types of samplers

Table 6.3.1 (continued)

Taxa	Organisms Collected from Black Creek	Collection Method[1]
Siphlonuridae		
Ameletus		P.S.
Baetidae		
Callibaetis		P
Baetis	+	P.S.
Centroptilum	+	S
Odonata		
Zygoptera		
Agrionidae		
Argia	+	S
Enallagma		P.S.
Anisoptera		
Gomphidae		
Dromogomphus		P
Gomphus		P
Aeshnidae		
Coryphaeschna		S
Macromiidae		
Macromia		P
Didymops		P
Libellulidae		
Tetragoneuria		P.S.
Celithemis		P.S.
Sympetrum		P
Libellula		P
Orthemis		P
Plecoptera		
Pteronarcidae		
Pteronarcys dorsata		S
Nemouridae		
Nemoura	+	S
UID Nemouridae	+	
Perlidae		
Perlesta	+	S
Acroneuria	+	S
Phasganophora capitata	+	S
Paragnetina		S
UID Perlidae	+	S
Perlodidae		
Isoperla/Diploperla	+	S
Taeniopterygidae		
Taeniopteryx	+	S
Coleoptera		
Amphizoidae	+	P.S.
Dytiscidae		
Oreodytes/Deronectes		P
Hydrophilidae		
Berosus	+	P.S.
Gyrinidae		
Dineutus		P

Table 6.3.1 (continued)

Taxa	Organisms Collected from Black Creek	Collection Method[1]
Elmidae		
Ancyronyx variegatus	+	S
Stenelmis	+	P.S.
UID Elmidae	+	S
Chrysornleidae		
Donacia	+	P.S.
Helodidae		P
Megaloptera		
Sialidae		
Sialis		S
Trichoptera		
Hydropsychidae		
Hydropsyche	+	S
Hydropsyche sp A	+	S
Cheumatopsyche	+	S
Macronemum	+	S
Philopotamidae		
Chimarra	+	S
Psychomyiidae		
Phylocentropus		P
Cyrnellus	+	S
Polycentropus	+	P.S.
Nyctiophylax	+	S
Neureclipsis	+	P.S.
Hydroptilidae		
Ochrotrichia	+	S
Oxyethira	+	S
Brachycentridae		
Brachycentrus numerosus	+	S
Leptoceridae		
Oecetis	+	P.S.
Leptocerid pupae		P.S.
Lepidoptera		
Pyralidae		
Nymphula		P
Cataclysta		P
Diptera		
Culicidae		
Chaoborus	+	P.S.
Tipulidae		
Tipula		P
Simuliidae-larvae pupae	+	S
Ceratopogonidae		
Bezzia/Probezzia	+	P.S.
Tabanidae		
Chrysops	+	P.S.
Empididae	+	S

Table 6.3.1 (continued)

Taxa	Organisms Collected from Black Creek	Collection Method[1]
Rhagionidae		
Atherix variegatus	+	S
Chironomidae		
Tanypoidinae		
Pentaneurini		
Ablabesmyia	+	P.S.
Conchapelopia	+	P.S.
Pentaneura	+	P.S.
Labrundinia		P.S.
Zavrelimyia		P
Larsia		P
Coelotanypodinae		
Tanypus		P
Anatopynia		P
Psectrotanypus		P.S.
Procladius	+	P.S.
Clinotanypus	+	P.S.
Coelotanypus		P
Orthocladiinae		
Corynoneura	+	S
Thienemaniella	+	S
Cricotopus	+	P.S.
Cardiocladius	+	P.S.
Nanocladius	+	P.S.
Eukiefferiella	+	P.S.
Brillia par	+	P.S.
Stenochironomus		S
Psectrocladius	+	P.S.
Orthocladius	+	S
Zalutschia		P.S.
Trichocladius	+	P.S.
Microcricotopus	+	S
UID Orthoclad V	+	S
UID Orthoclad W	+	S
UID Orthoclad X	+	S
UID Orthoclad Y	+	S
Diamesinae		
Potthastia longimanus	+	S
Chironominae		
Chironomini		
Paralauterborniella		P.S.
Paratendipes		P.S.
Microtendipes	+	P.S.
Chironomus	+	P.S.
Cryptochironomus	+	P.S.

Table 6.3.1 (continued)

Taxa	Organisms Collected from Black Creek	Collection Method[1]
Harnischia	+	P.S.
Polypedilum	+	P.S.
Polypedilum fallax	+	P.S.
Pseudochironomus		P.S.
Phaenopsectra	+	P.S.
Tribelos	+	P.S.
Parachironomus		P.S.
Cryptotendipes		P
Xenochironomus		P
Dicrotendipes	+	P.S.
Paracladopelma		P.S.
Chironomini sp A (Roback)	+	S
Chironomini sp C (Roback)		S
UID Chironomini A	+	P.S.
Tanytarsini		
Micropsectra		S
Cladotanytarsus	+	P.S.
Rheotanytarsus	+	P.S.
Tanytarsus	+	P.S.

Table 6.3.2 Mean number of Cladotanytarsus, Harnischia, and Cryptochironomus/m^2 collected at Robinson Impoundment, January - December, 1975

Group	Station	Cladotanytarsus	Harnischia	Cryptochironomus
I	A-1	8	5	26
	C-1	8	1	5
	E-3	-	1	14
II	A-3	-	2	1
	C-3	-	7	1
	D-1	1	13	1
III	D-3	2	6	1
	F	56	15	6
	G	125	14	19
IV	E-1	-	2	5
	F-S	2	11	5
	G-S	98	33	23

Table 6.3.3 Mean number of *Procladius*/m^2 collected at Robinson Impoundment, January - December, 1975

Group	Station	Procladius	Procladius (aberrant)
I	A-1	156	25
	C-1	92	27
	E-3	51	5
II	A-3	134	1
	C-3	230	2
	D-1	175	2
III	D-3	89	-
	F	153	13
	G	265	15
IV	E-1	34	138
	F-S	75	95
	G-S	114	22

Table 6.3.4 Mean number of Clinotanypus/m^2 collected at Robinson Impoundment, January - December, 1975

Group	Station	Mean Number/meter^2
I	A-1	2
	C-1	1
	E-3	1
II	A-3	-
	C-3	-
	D-1	1
III	D-3	-
	F	6
	G	1
IV	E-1	5
	F-S	39
	G-S	26

Table 6.3.5 Mean number of Oligochaeta/m^2 collected at Robinson Impoundment

Station	Mean Number/meter^2
A-1	225
C-1	184
E-3	377
A-3	818
C-3	279
D-1	740
D-3	251
F	417
G	273
E-1	133
F-S	336
G-S	453

Table 6.3.6 Diversity estimates (d) of benthos collected in Robinson Impoundment, January - December, 1975

	STATIONS											
	A-1	A-3	C-1	C-3	D-1	D-3	E-1	E-3	F	F-S	G	G-S
Jan.	1.99	0.73	1.49	1.98	1.98	2.06	2.33	1.58	2.54	2.19	3.16	2.71
Feb.	2.22	0.72	2.13	2.23	1.72	2.13	1.22	1.79	3.07	2.72	2.88	3.78
Mar.	2.19	1.87	2.86	2.01	1.73	1.97	1.78	2.22	2.01	3.22	2.56	3.92
Apr.	2.82	2.10	3.11	2.61	1.73	2.18	1.20	2.19	2.30	2.88	3.10	3.91
May	2.98	1.49	2.56	1.61	2.27	2.95	2.35	2.62	2.99	3.03	2.62	3.62
Jun.	0.83	2.10	3.18	1.51	0.73	2.89	2.69	2.47	2.34	3.10	2.15	2.79
Jul,	3.04	1.06	2.10	0.64	1.45	2.40	2.77	1.00	2.91	3.19	3.15	3.56
Aug.	2.17	1.53	2.52	0.87	1.18	2.99	0.35	1.39	2.32	3.30	2.52	2.98
Sep.	2.01	1.49	1.73	0.44	1.78	2.23	0.0	0.47	2.25	1.90	1.45	2.71
Oct.	2.89	1.48	1.41	1.30	0.74	1.55	0.0	0.82	2.56	1.55	2.70	2.73
Nov.	1.70	1.20	1.84	1.74	1.09	1.88	1.70	2.70	2.70	1.91	2.45	3.90
Dec.	1.72	1.44	2.81	2.02	2.21	2.62	2.05	2.28	2.91	2.32	1.99	4.21

Table 6.3.7 Dominant benthic taxa collected on artificial substrates in Black Creek, January - December, 1975

1975	Station H Organisms	Station H No. Collected	Station H % of Total	Station K Organisms	Station K No. Collected	Station K % of Total	Station I Organisms	Station I No. Collected	Station I Total
Jan.	Hydracarinid	1	100	Hydropsyche	10	67	Simuliidae larvae	6	38
				Neureclipsis	3	20	Taeniopteryx	3	18
Feb.	Polypedilum	7	54	Trichocladius	9	56	Stenonema	4	25
	Eukiefferiella	3	23	Eukiefferiella	3	19	Oligochaetes	3	19
							Brachycentrus	3	19
Mar.	Polypedilum	38	64	Eukiefferiella	92	-	Stenonema	12	23
	Cricotopus	11	19	Trichocladius	33	-	Simuliidae pupae	10	19
	Psectrocladius	4	7	Hydropsyche	28	-	Rheotonytarsus	8	15
Apr.	Cricotopus	26	58	Hydropsyche	47	47	Simuliidae larvae	54	35
	Polypedilum	8	18	Eukiefferiella	29	29	Polypedilum	47	30
	Oligochaetes	5	11	UID Orthoclad X	20	20	Perlesta	16	10
							Macronemum	7	5
May	Polypedilum	240	12	Eukiefferiella	35	29	Polypedilum	11	16
	Polycentropus	98	25	Polypedilum	26	22	Microtendipes	8	11
	Planariidae	18	4	Hydropsyche	24	20	Stenonema	7	10
				Perlesta	11	9			
Jun.	Hydropsyche	149	46	Polycentropus	5	22	Missing		
	Polypedilum	86	26	Polypedilum	5	22			
	Macronemum	34	10	Trichocladius	3	13			
Jul.	Hydropsyche	410	49	Macronemum	41	41	Missing		
	Polycentropus	227	27	Polypedilum	12	12			
	Planariidae	79	10	Cryptochironomus	9	9			
	Polypedilum	24	6						

Table 6.3.7 (continued)

1975	Station H Organisms	Station H No. Collected	Station H % of Total	Station K Organisms	Station K No. Collected	Station K % of Total	Station I Organisms	Station I No. Collected	Station I Total
Aug.	Hydropsyche	23	88	UID Orthoclads	10	24	Missing		
				Polypedilum	8	19			
				Ablabesmyia	8	19			
				Oligochaetes	5	12			
Sep.	Hydropsyche spp	102	55	Polypedilum	20	29	Tanytarsus	110	28
	Hydropsyche sp	32	17	Ablabesmyia	9	13	Microtendipes	66	17
	Polypedilum	20	11	Hydropsyche	9	13	Polypedilum fallax	42	11
							Polypedilum	30	8
Oct.	Polypedilum	47	34	Oligochaetes	6	19	UID Orthoclad W	56	24
	Hydropsyche	46	33	Polypedilum	6	19	Oligochaetes	25	11
	Oligochaetes	20	14	Cryptochironomus	3	9	UID Orthoclad X	25	11
	Polycentropus	19	13				Pentaneurini	18	8
Nov.	Neureclopis	116	42	Oligochaetes	6	15	UID Orthoclad X	37	19
	Hydropsyche spp	127	45	Cryptochironomus	5	13	UID Orthoclad S	16	8
	Polypedilum	24	9				Tanytarsus	14	7
							Cricotopus	13	7
Dec.	Neureclipsis	36	57	Hydropsyche spp	31	35	UID Orthoclad X	101	59
	Polypedilum	13	20	UID Orthoclad Y	9	13	UID Orthoclad S	11	6
	Hydropsyche sp	9	14	Neureclipsis	7	10	Stenonema	10	6

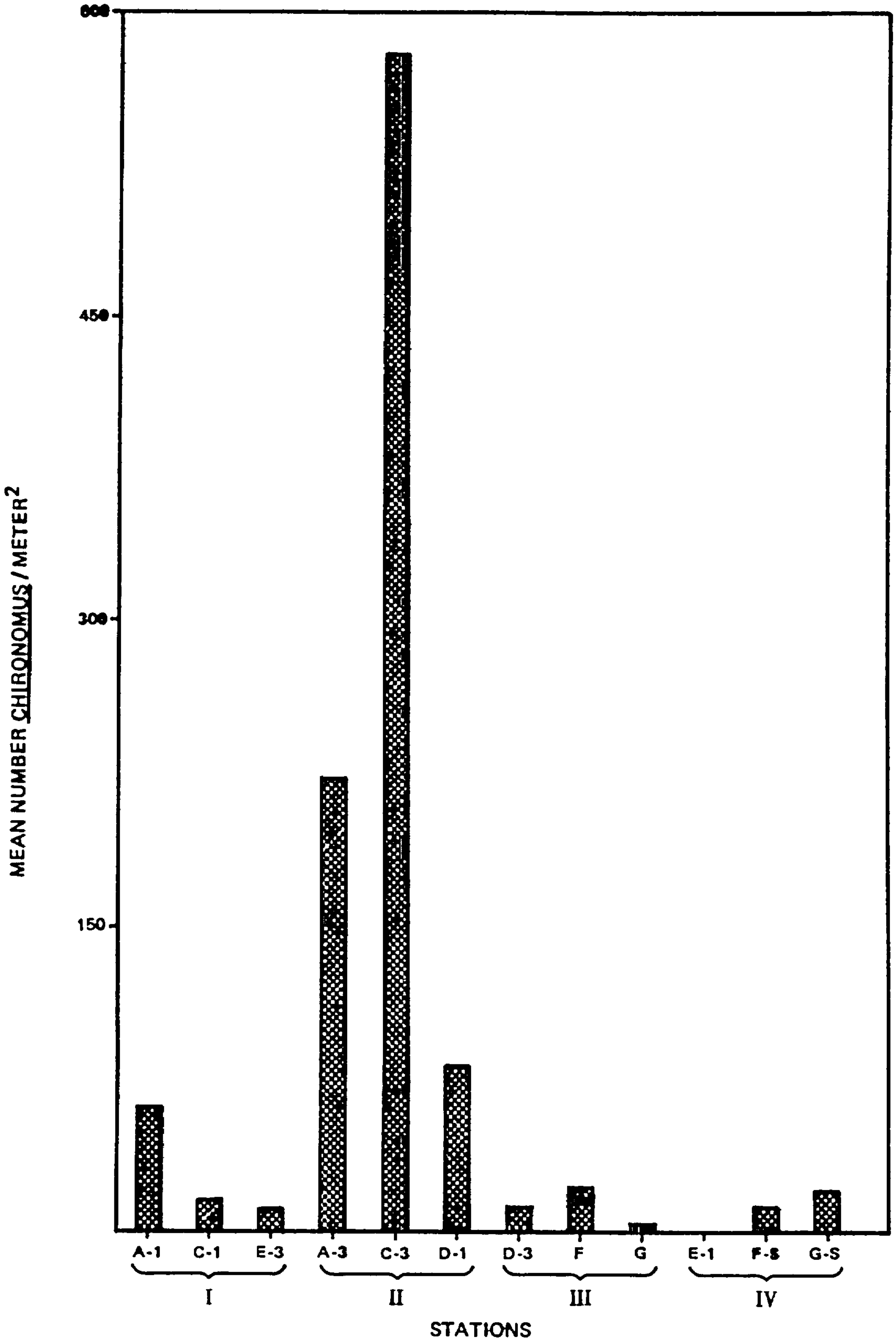

Figure 6.3.1 Monthly mean number of *Chironomus*/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

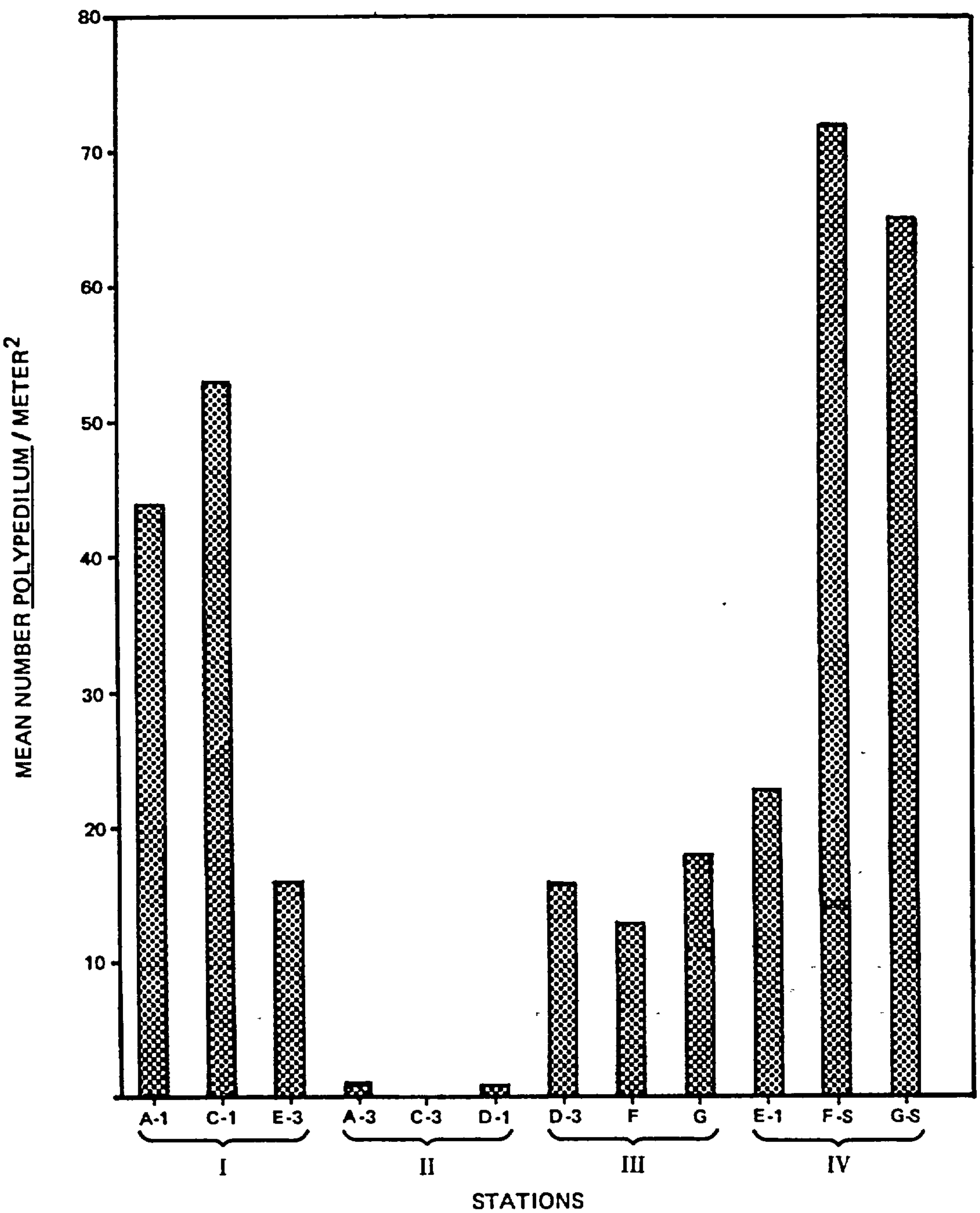

Figure 6.3.2 Monthly mean number of Polypedilum/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

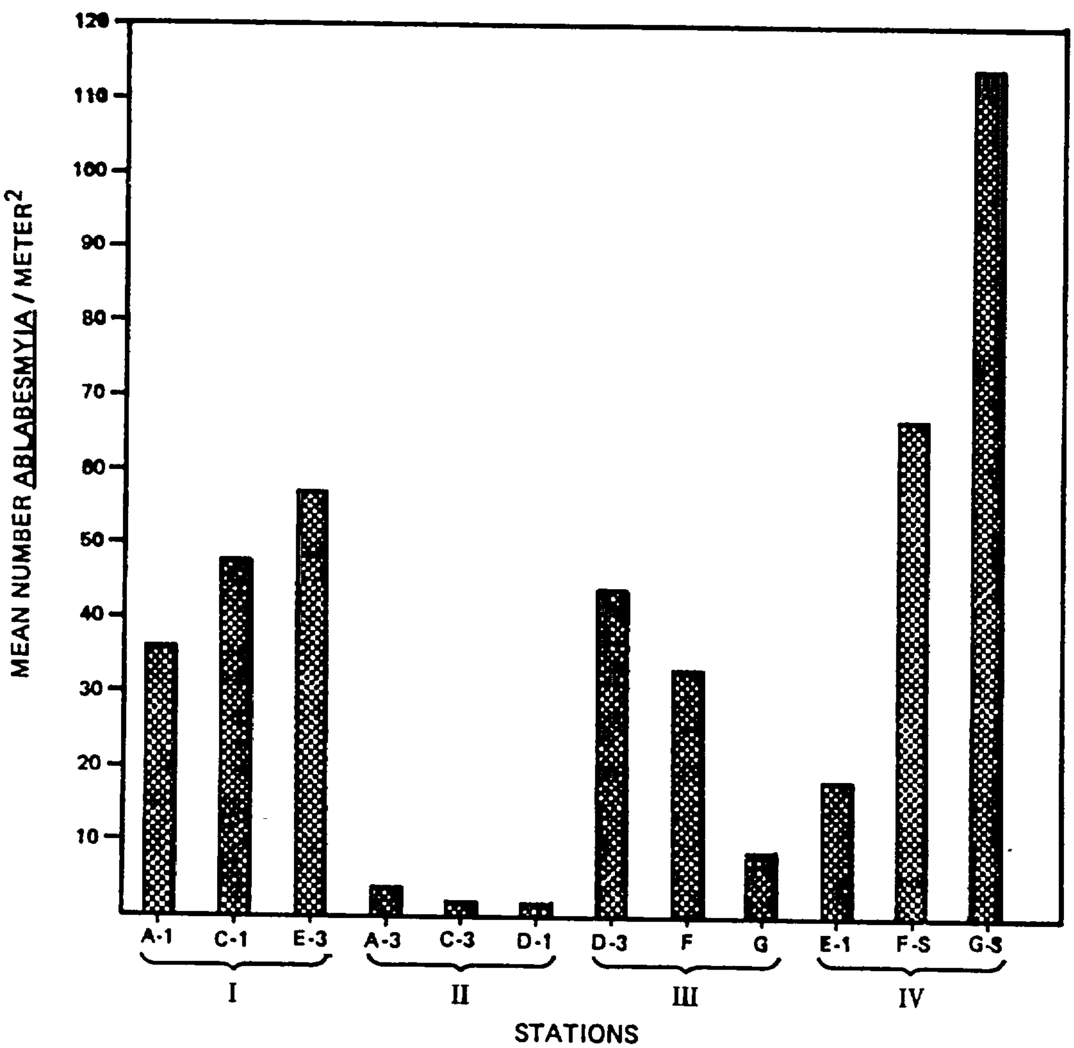

Figure 6.3.3 Monthly mean number of Ablabesmyia/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

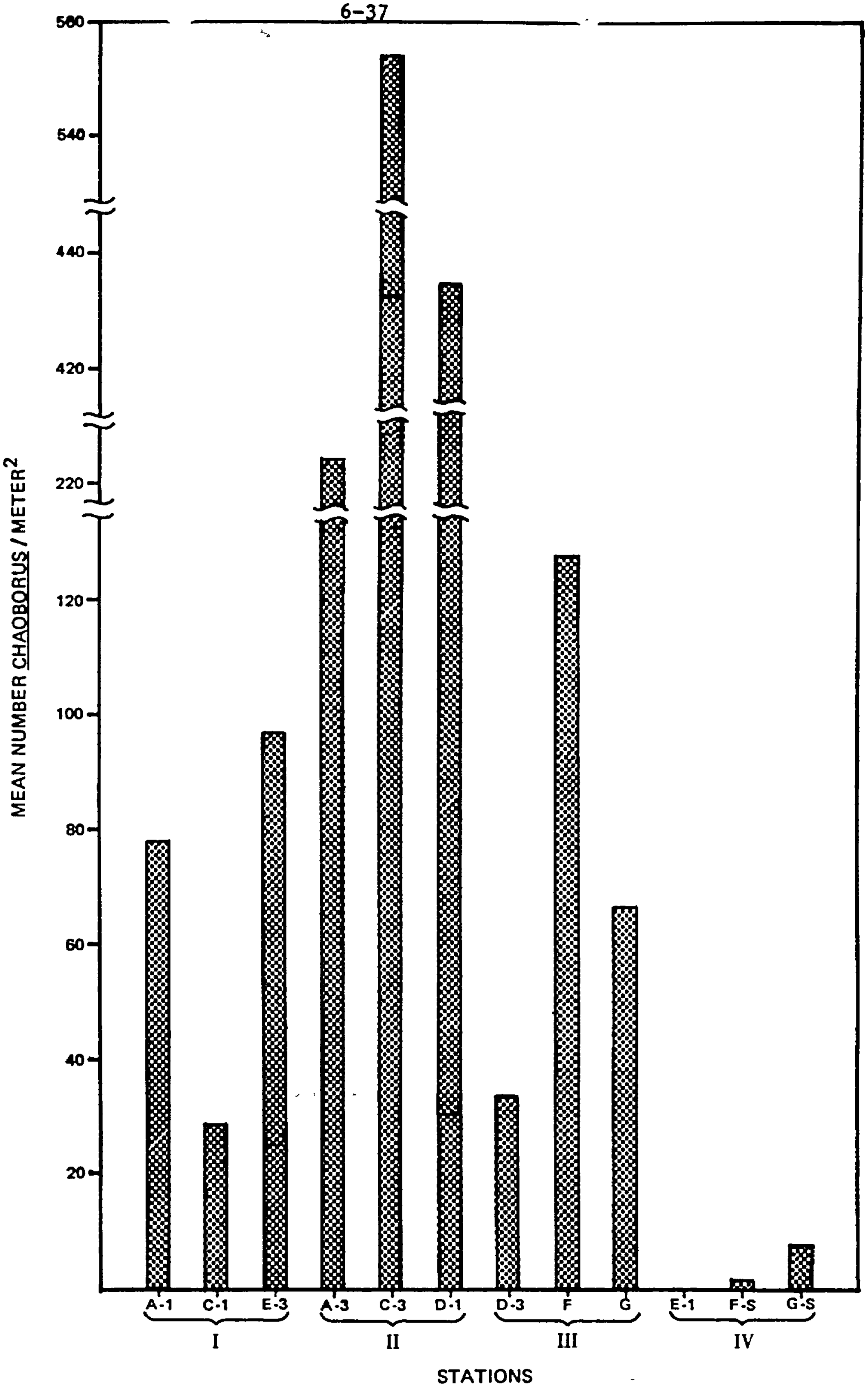

Figure 6.3.4 Monthly mean number of Chaoborus/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

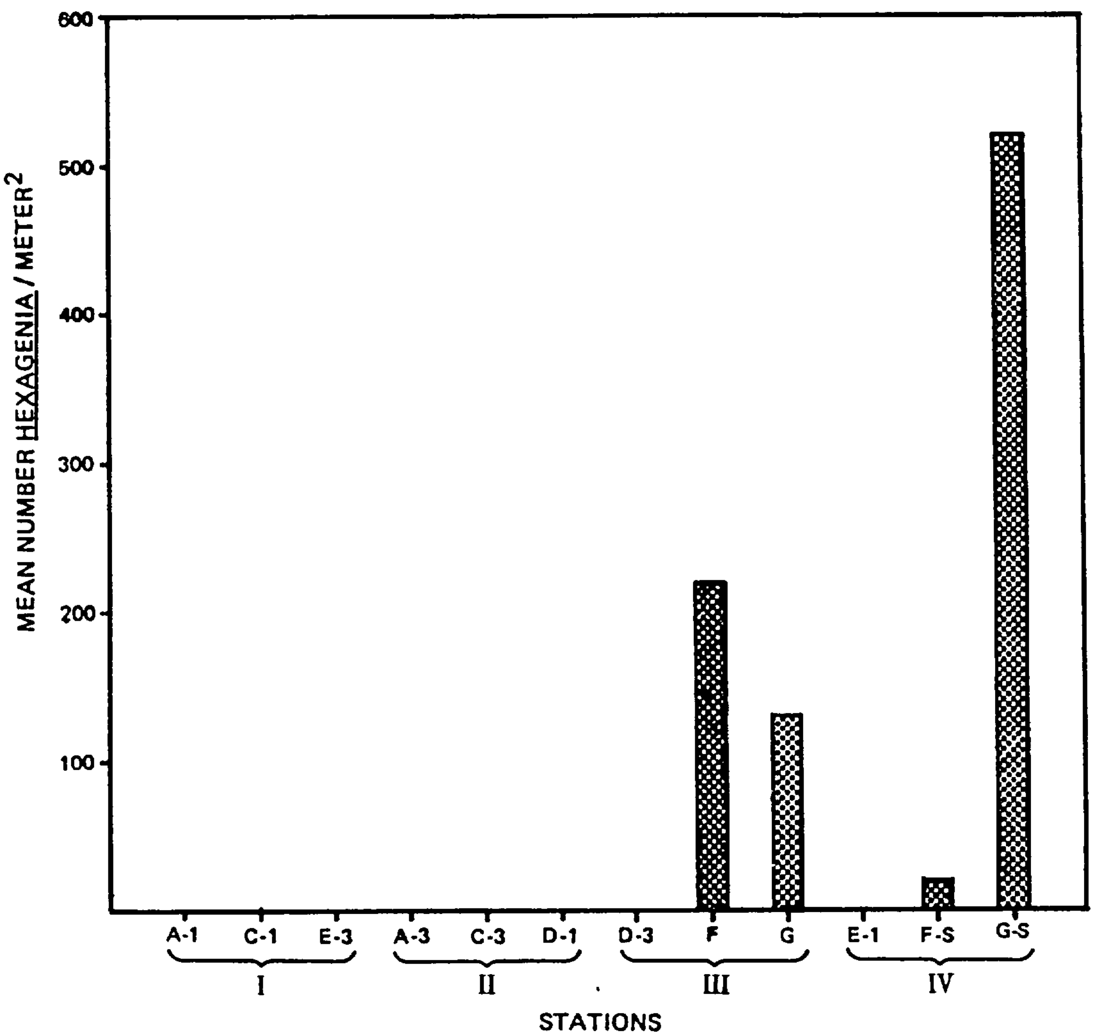

Figure 6.3.5 Monthly mean number of Hexagenia/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

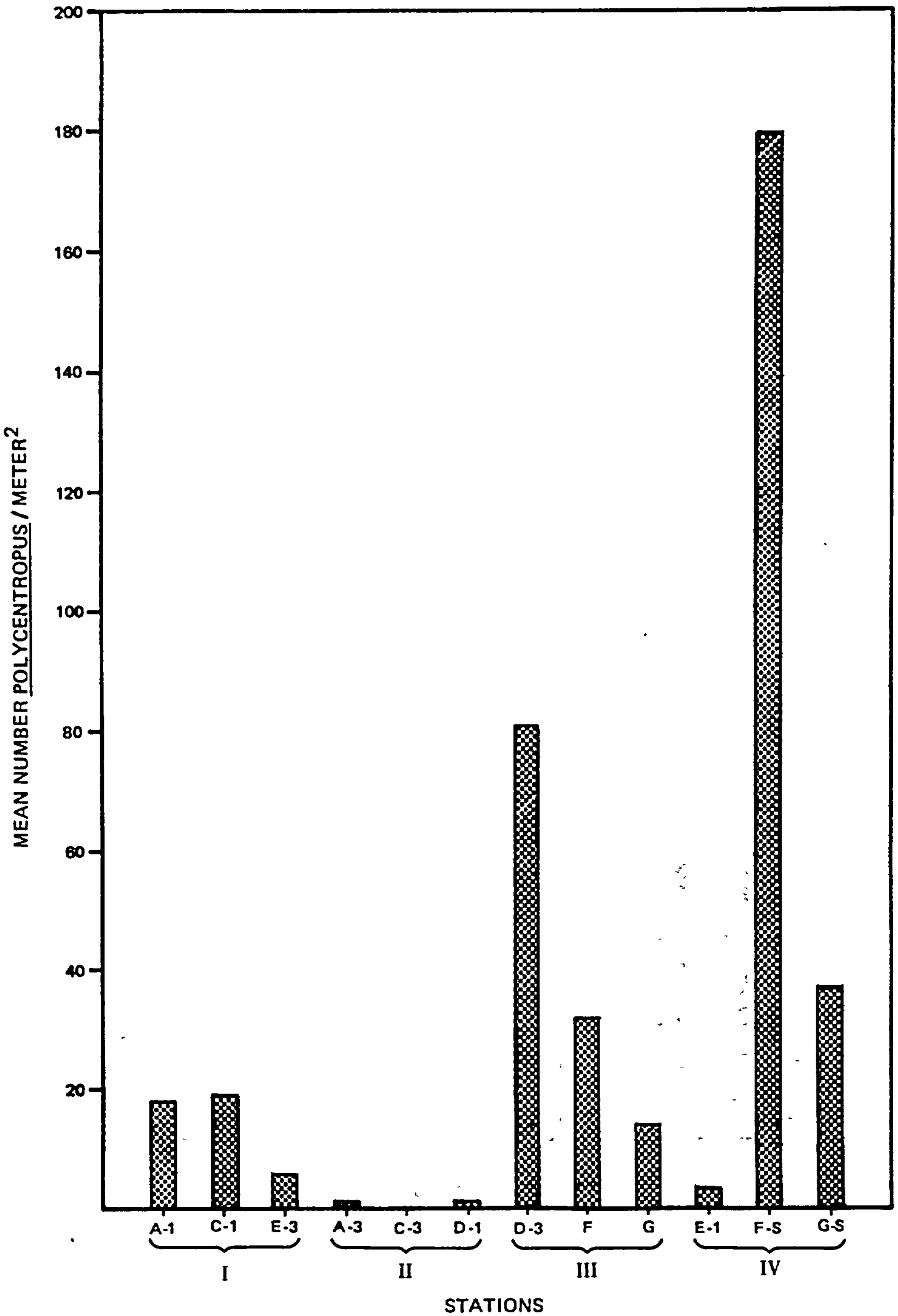

Figure 6.3.6 Monthly mean number of Polycentropus/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

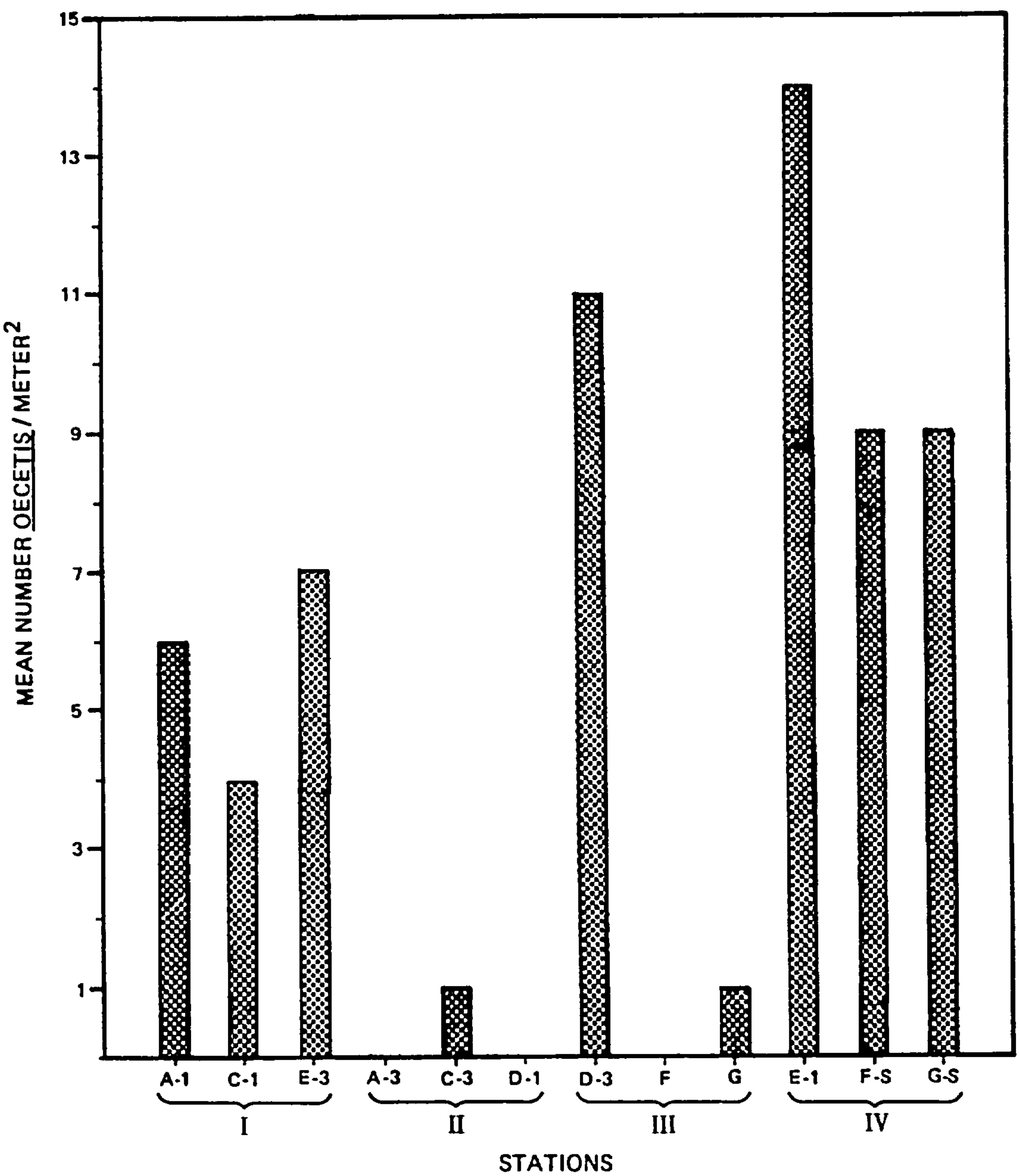

Figure 6.3.7 Monthly mean number of Oecetis/meter^2 collected at each of the twelve benthic sampling stations in the Robinson Impoundment, January through December 1975

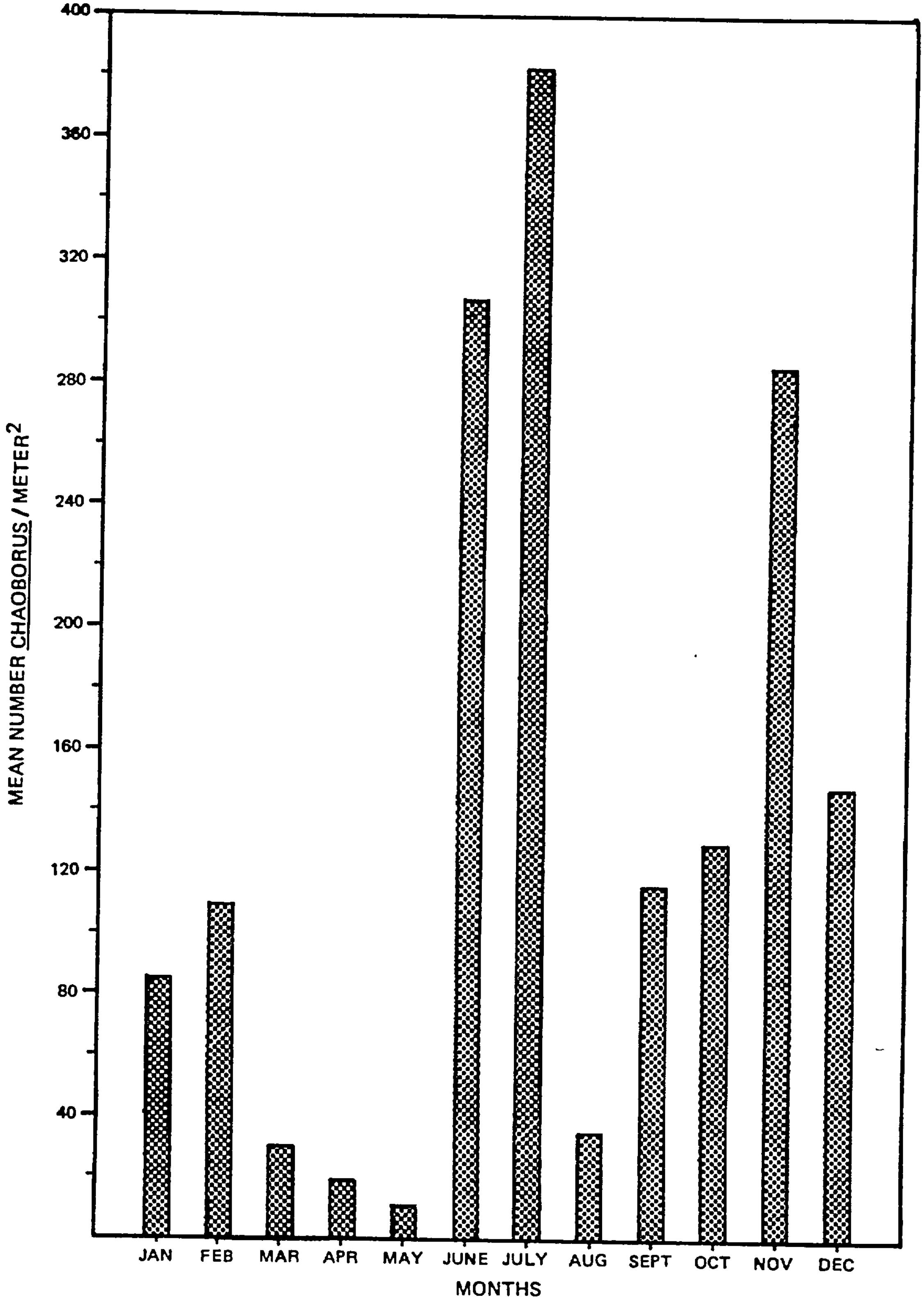

Figure 6.3.8 Monthly mean number of Chaoborus/meter^2 collected in the Robinson Impoundment, January through December 1975.

7.0 Aquatic Vegetation

7.1 Introduction

A study of the aquatic macrophytes found in the Robinson Impoundment and Black Creek was initiated in the fall of 1974 to assess their importance in the aquatic ecosystem and to identify any influence of the heated effluent from the H. B. Robinson Steam Electric Plant on the number of species present, their abundance and distribution.

Field work proceeded on a quarterly basis until the summer of 1975 when a more intensive effort was begun. During this period the entire impoundment was investigated and the aquatic vegetation was plotted on a scale map as prescribed in the EPA Region IV Basic Guide to the Design of 316 Demonstrations. Black Creek above and below the impoundment at Stations H, J, and K (Figure 7.1.1) was also studied in order to describe the aquatic vascular vegetation occurring there.

For the purposes of this report, the definition of "aquatic vascular vegetation" or "aquatic macrophytes" was taken from Muenscher (1944). "Aquatic plants . . . are those species which normally start in water and must grow for at least part of their life cycle, either completely submersed or emersed." It is difficult, however, to adhere strictly to a single definition because many species, although not true "aquatics," must be included in this report for they receive direct influences from the Robinson Impoundment and Black Creek. Red maple (*Acer rubrum*), black willow (*Salix nigra*), tag alder (*Alnus serrulata*), Atlantic white cedar (*Chamaecyparis thyoides*), and *Viburnum nudum* , for example, are often found in low marshy areas along the shores of the impoundment and the seasonally innundated flood-plain along Black Creek. Sculthorpe (1967) states that it may be unwise to stick entirely to a single definition in the following:

> "It is difficult to suggest a definition of vascular hydrophytes that is universally acceptable yet not utterly artificial. The difficulty arises mainly because aquatic habitats cannot be sharply distinguished from terrestrial ones. In most climates there is a seasonal fluctuation of the water table. Habitats with standing

> water for most of the year may dry out completely in the summer whilst normally terrestrial soils may be flooded during a rainy season. At no time is there an abrupt transition from dry through waterlogged to submerged soils. The reversion of vascular plants to aquatic life has involved colonization of all these transitional habitats as well as the water itself, and some of the marginal sites that are periodically flooded have come to possess their own distinctive plant associations."

The role of aquatic vascular plants in the aquatic ecosystem is complex and varied. As primary producers they add to the supply of food and oxygen for other organisms throughout a range of trophic levels. Upon their death and decomposition they add carbon dioxide and nutrients to the water for use in photosynthesis by lower plants. The aquatic macrophytes provide shelter for fish, reptiles and amphibians and serve as breeding areas for certain species (Hotchkiss, 1941; and Odum, 1956). Some species of invertebrate organisms attach to the macrophytes for shelter, access to food and/or for breeding. A variety of plant parts such as leaves, fruits, roots, and rhizomes provide a good food source for invertebrates, fish, birds, and mammals. Submerged aquatic plants with finely dissected leaves, such as Myriophyllum pinnatum, which is widely distributed in the Robinson Impoundment, generally support significant numbers of invertebrates (Hotchkiss, 1941) which are often eaten by fish. Table 7.1.1 taken from Sculthorpe (1967) and Table 7.1.2 assimilitated from Martin, et al. (1951) illustrate some genera of aquatic plants used for food and shelter by fish, birds, and mammals. Emergent species also reduce erosion and add stability to the shoreline.

However, there are some negative aspects to vast areas of aquatic vegetation (Hotchkiss, 1941). While it is true that higher plants furnish food and make lakes more "habitable" they "destroy the habitat for both themselves and their animal associates. They add oxygen . . . but cut down on the ability of the water to absorb it . . . . They furnish ducks with essential food, but their contribution of decomposing material may periodically help to reduce oxygen to the point where botulism can take its toll. They support an abundance of fish food, but their dense growths may favor an increase of snails and other intermediate hosts of fish parasites."

While furnishing habitat for other members of the ecosystem, plants may also contribute to its destruction and create additional problems for man (Blackburn et al., 1968; and Holm et al., 1969). Dense weed growth can hinder navigation, destroy recreational areas, present health hazards, and generally reduce the suitability of the waterways for the purposes for which they were constructed. Aquatic macrophytes provide a necessary link in the ecosystem but their overabundance can be detrimental.

7.2 Vegetational Distributions

7.2.1 Methods

During the field sampling, the entire impoundment was investigated by boat and by wading along the shore.

When possible, plants were identified and labeled in the field. Specimens which could not be readily identified were numbered and plotted on the map by number. Upon returning to the laboratory such specimens were identified. Plants were pressed, dried, and mounted using standard herbarium procedures, and stored in the CP&L herbarium collection.

Taxonomic keys used in the identification of the plants encountered include Radford et al. (1968); Fassett (1957); Eyles and Robertson (1944); Musenscher (1944); and Justice and Bell (1968). Some plants were taken to the North Carolina State University herbarium for comparison with specimens maintained there. Several were also sent to Dr. E. O. Beal, Western Kentucky University for annotation. Nomenclature follows that of Radford et al. (1968). The information depicted on the map (Figure 7.2.1 - Figure 7.2.4) was assimilated during the growing season of 1975. Seasonal (winter dieback) and successional changes in species composition, distribution, and biomass are therefore not reflected in the map. Included with the map, which depicts the entire Robinson Impoundment and areas of significant beds of aquatic plants, are facing page maps (Figures 7.2.1a, 7.2.2a, and 7.2.3a) which indicate physiographic and man-made features influencing the distribution of aquatic vegetation along the shoreline of the impoundment. As the map is intended to show "major beds of aquatic vascular vegetation," a minimum size for an area to be illustrated was necessary. Areas appearing on the map are approximately 18.6 m^2 (200 ft^2) as a practical lower limit. Plant species which occur as individuals or in groups smaller than the lower size limit do, however, appear in the species list (Table 7.2.1) for the impoundment and Black Creek and are included in discussions and descriptions of the aquatic communities. Vegetative communities along Black Creek above and below the impoundment are described in the text but do not appear on the map.

7.2.2 Results and Discussion

Much of the area surrounding the Robinson Impoundment supports vegetation which typifies the Sandhill community. The long leaf pine-turkey oak-wire grass association is predominant on the dry, sandy, upland areas. The species of primary importance include long leaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), turkey oak (*Quercus laevis*), blackjack oak (*Q. marilandica*), and post oak (*Q. stellata*). The ground cover is composed mainly of wire grass (*Aristida stricta*). Other herbaceous species identified include dayflower (*Commelina erecta*), pine-barren gentian (*Gentiana atumnalis*), and rose pink (*Sabatia angularis*). A species list which includes all plants identified and/or collected in the area is included as Table 7.2.1. This table consists of species common to Sandhill communities and lowland areas, although fieldwork has been directed primarily to aquatic species in the Robinson Impoundment and along Black Creek.

One hundred and thirty eight species have been identified in and around the Impoundment. Of this number, seventy eight are aquatic plants or have been found in lower or periodically flooded areas. Many of the same aquatic species identified in the Robinson Impoundment were found to inhabit Prestwood Lake by Coker (1911). He lists the "aquatic plants" occurring in the lake as *Brasenia schreberi*, *Nymphoides aquaticum*, *Potamogeton diversifolius*, *Potamogeton heterophyllus*, *Nymphaea advena* (*Nuphar luteum* spp. *macrophyllum*), *Utricularia fibrosa*, *Utricularia biflora*, and *Mayaca fluviatalis*. Other aquatic species were distributed around the borders of the impoundment.

Aquatic species appearing on the map (Figure 7.2.1 - Figure 7.2.4) of major beds of vascular vegetation include:

Myriophyllum	Myriophyllum pinnatum
Water lily	Nymphaea odorata
Water shield	Brasenia schreberi
Spatter dock	Nuphar luteum
Bur-reed	Sparganium americanum
Golden club	Orontium aquaticum
Pipewort	Eriocaulon compressum
Pondweed	Potamogeton diversifolius
Bulrush	Scirpus etuberculatus
Dulichium	Dulichium arundinaceum
Spike rush	Eleocharis baldwinii
Juncus	Juncus repens

These species occur in large enough areas to be plotted conveniently on the map. Other plants important in the ecosystem are enumerated and discussed in the text.

Figure 7.2.1 covers approximately the lower quarter of the impoundment. Aquatic vegetation is quite sparse except in the cove in the northeastern portion which is more protected from wave action. The dam and the southwest corner are covered with rip-rap (large rocks) which do not provide a suitable substrate for vegetation (see Figure 7.2.1a). Scattered red maple (Acer rubrum), broom sedge (Andropogon virginicus), and Juncus effusus occur to a limited extent here. The middle portion of the western shore has a predominantly sandy substrate and supports small populations of Juncus effusus, Myriophyllum pinnatum and the submerged, mat-forming spike-rush (Eleocharis baldwinii). The northwestern portion is largely devoid of vegetation except for scattered areas of Juncus repens and Eleocharis baldwinii, as rip-rap has also been placed in this section during construction of the discharge canal. The eastern shore supports a larger amount of vegetation especially in the more protected areas. In addition to species appearing on the map, populations of alder (Alnus serrulata), black willow (Salix nigra), red maple, Peltandra virginica, and Panicum hemitomon are well represented along the shore in this section. Figures 7.2.5 and 7.2.6 are photographs illustrating the rip-rap and sandy areas found in this portion of the impoundment.

Figure 7.2.2 represents the next portion of the impoundment northward. The entire western side of the impoundment along the discharge canal supports no beds of aquatic vascular plants large enough to be illustrated on the map. This is due to the sandy substrate and rip-rap placed along the shoreline. Occurring along the shoreline are red maple, broom sedge, and Juncus canadensis. The eastern shore supports limited areas of aquatic vascular macrophytes. Boat docks, swimming areas, and other activities of man have removed a portion of this area for colonization by aquatic vegetation (see Figure 7.2.2a). Alder, red maple, Panicum hemitomon, Peltandra virginica, cat-tail (Typha latifolia), and Juncus spp. also are found along this shoreline in areas which have not been disturbed for residential purposes.

Figure 7.2.3 depicts the major beds of aquatic vascular vegetation found in the area where the heated effluent empties into the impoundment. The western shore which borders the discharge canal is lined with rip-rap to a great extent. Major species found here in addition to those on the map include thoroughwort (Eupatorium sp.), red maple, cat-tail, and Panicum hemitomon. The area to the north of the mouth of the canal is generally low and marshy along the shoreline and except for the cove area directly north of the discharge has considerable vegetation including red maple, alder, Panicum hemitomon and cat-tail as species which do not appear on the map. The cove north of the discharge is shown in Figure 7.2.7. Spike-rush (Eleocharis baldwinii) was first noted near the mouth of the discharge canal in February, 1976. This species was not found in this area during the sampling which took place in the summer of 1975. The reduction of this species during the summer months is apparently due to elevated water temperatures in this area.

The southeastern portion of the impoundment in this section is dotted with houses and boating facilities, yet does support some aquatic vegetation. The cove which is formed in the old Big Beaverdam Creek bed and surrounding edges is covered with extensive beds of plants. Peltandra virginica, Panicum hemitomon, cat-tails, bladderworts (Utricularia spp.), and several species of Sagittaria are found here, along with an abundance of Sparganium americanum. The northeastern areas are predominantly shallow and marshy. The plants mentioned above in addition to floating heart (Nymphoides aquaticum) and Eleocharis baldwinii are prevalent. On slightly higher ground alder, willow, and red maple make up the dominant woody vegetation.

Figure 7.2.4 illustrates the upper portion of the impoundment above the S. R. 346 bridge. It is in this section that aquatic vascular vegetation attains its greatest development. Myriophyllum and more of the broader leaved floating species such as the water lilies (Nymphaea odorata and Nuphar luteum), along with emergent varieties like golden club (Orontium aquaticum), Peltandra virginica, pipewort (Eriocaulon compressum), and several species of Sagittaria also occur more frequently in this area. A significant factor in the increased development of the emergent and floating species in this portion of the impoundment is protection from wave action. The protected, shallow coves and marshy sections in this area of the impoundment contain silt and organic material which is suitable for the colonization of aquatic macrophytes. Although aquatic plants vary considerably in resistance to wave action, it is the submerged forms with strong rhizomes or those occurring in rosettes (Sculthorpe, 1967), such as Eleocharis baldwinii, Juncus repens, and Sagittaria graminea, which best survive wind and waves. In more exposed areas of the lower impoundment turbulence has removed finer silt and organic matter which provide the necessary substrate for many species. Figure 7.2.8 pictorally depicts shoreline vegetation which is typical of this section of the impoundment.

Predominant emergent species occurring along the shoreline include cat-tails, Panicum hemitomon, bulrush (Scirpus cyperinus), sedge (Carex lurida), red maple, black willow, Juncus canadensis, and J. effusus. On the cove on the western shore bur-reed (Sparganium americanum) and golden club (Orontium aquaticum) are common in the marsh where a small creek enters the area. Vast beds composed primarily of Myriophyllum and Nymphaea are found in the shallow northeastern section. Bog moss (Mayaca fluviatalis) and Proserpinaca pectinata are scattered in marshy areas in this section of the impoundment. Scirpus etuberculatus, which is found in the upper portion of the impoundment is pictured in Figure 7.2.9.

Station J (Figure 7.1.1) is located in a transitional area between the upper impoundment and Black Creek itself. The stream channel and adjacent flooded areas support growths of Scirpus etuberculatus, bur-reed (Sparganium americanum), Myriophyllum, and pondweed (Potamogeton diversifolius) as major species. Along the channel are tussocks of sedges, rushes, and grasses such as Carex lurida, Scirpus cyperinus, several species of Juncus and Panicum hemitomon. Also present are cat-tails, and small lowland tree species such as red maple, black willow, tag alder, sweet bay (Magnolia virginiana), Viburnum nudum, leatherwood (Cyrilla racemiflora), Atlantic white cedar (Chamaecyparis thyoides), and bald cypress (Taxodium distichum). Among the tussocks are shallow rivulets or sloughs which may dry up during low flow periods. Along with the species mentioned earlier for the stream channel, spike rush (Eleocharis quadrangulata and E. equisitoides) and pipeworts are found here. As the distance from the main channel increases and elevation of the terrain rises, more large trees are encountered, including Atlantic white cedar, red maple, and bald cypress.

The bottomland along Black Creek at Stations H and K (Figure 7.1.1) is a seasonally flooded diverse community composed primarily of lowland hardwoods, bald cypress and a few pines. Figure 7.2.10 is a picture of the community typical of Black Creek below the dam. The predominant tree species are gum (Nyssa spp.), bald cypress, Atlantic white cedar, water oak (Quercus nigra), and loblolly pine (Pinus taeda). Other trees along the Black Creek flood plain and adjacent areas include sweet bay, red maple, red bay (Persea borbonia) and black willow. Included in the understory are tag alder, sweet pepperbush (Clethra alnifolia), leatherwood (Cyrilla racemiflora), sparkleberry (Vaccinium arboreum), and Myrica spp. Herbaceous species include giant cane (Arundinaria gigantea), netted chain-fern (Woodwardia areolata), knotweed (Polygonum hydropiperoides), and Iris spp.

Aquatic macrophytes identified in the creek at Station H include Eleocharis baldwinii, Sagittaria engelmanniana, Juncus effusus, and Scirpus sp. Station K is quite similar to H except that it is more undisturbed and supports a few additional species of aquatic plants. Eleocharis baldwinii, Juncus repens, Nuphar luteum, Scripus etuberculatus, and Eriocaulon compressum are present here.

7.2.3 Factors Influencing Distribution

A complex set of interacting factors act separately and together to determine the distribution of aquatic vegetation. Among these parameters are water chemistry (including dissolved nutrients), substrate, turbulence, light and temperature.

Moyle (1945) in discussing water chemistry states that, "Although water chemistry appears to be the most important single factor influencing the general distribution of aquatic plants in Minnesota, field observations show that the type of bottom soil and the physical nature of the body of water greatly influence the local distribution of a species within its range of chemical tolerances." Sculthorpe (1967) notes that hardness or alkalinity expressed as ppm $CaCO_3$ is often used as a measure of nutrient status of water. He considers levels below 15 ppm to be an indication of a nutrient poor status. The Robinson Impoundment generally possesses levels of hardness (as $CaCO_3$) of less than 2 ppm (Table 3.4.1). Moore (1950) states that a "high carbonate" lake usually supports abundant aquatic vegetation. (See Water Chemistry, Section 3.4.) Nitrogen, phosphate, iron, sulfate are other important nutrients (Sculthorpe, 1967) which are not in abundance in the Robinson Impoundment (Exhibit 2.4).

The influence of substrate on the distribution is primarily through the texture and particle size rather than through the nutrients contained in it (Sculthorpe, 1967). The loose sands of the Sandhill community now form much of the substrate along the shores of the Robinson Impoundment. Coarse sand and gravel sometimes shifting with wave action provide a poor substrate for rooted aquatic plants (Hotchkiss, 1941). Bare rocks, such as the rip-rap found on portions of the shore in the impoundment also do not facilitate colonization. Figures 7.2.1a, 7.2.2a, and 7.2.3a illustrate some areas which have unsuitable substrates for vegetative growth.

Turbulence is another key factor in determining the distribution of aquatic vegetation in the Robinson Impoundment. Sculthorpe (1967) states that, "On large lakes, reed-swamp" (emergent hydrophytes) "may be completely lacking or limited to shallow bays . . . . The smaller and less exposed the lake, the greater is the extent of reed-swamp, and the more likely that floating-leaved vegetation which is generally still less tolerant of wind and waves, will also be present." The shallow areas in the upper part of the impoundment and the cover occurring further down are more protected from wind and waves and as a rule, support larger areas of aquatic plants than the more exposed, open water shoreline. During windy periods, up-rooted vegetation, especially <u>Myriophyllum</u>, has been noted piled up along the shore.

Light penetration affects the depth to which photosynthesis can occur. Aquatic macrophytes may colonize depths having light intensities 1% to 2% of the intensity of the surface (Sculthorpe, 1967). The mean secchi depth, which can be related to light transmission, has been found to be 1 meter (3.3 feet) for the Robinson Impoundment (see Section 5.3.1 for further discussion). In the Robinson Impoundment rooted aquatics have been found in areas having a suitable substrate at depths of approximately 2 meters (6.6 feet). The "dark colored" nature of the water reduces light penetration in the impoundment so that only the shallower areas are available to rooted plants. Shading provided by the floating leaved species, such as *Nymphaea odorata*, *Nuphar luteum* and *Brasenia schreberi*, also reduces light so that submerged forms are restricted.

For the assessment of the impact of the effluent from the Robinson Plant on the aquatic macrophytes in the impoundment, temperature must be a primary consideration in evaluating the distribution of aquatic vegetation. Sculthorpe (1967) suggests that natural solar heating of a body of water may be greatest in slow moving swamps and ponds. The surface temperatures will generally be close to the air temperature if wind caused turbulence is not great. Heating of this type is thus more of a factor in the isolated coves and shallow, marshy areas of the Robinson Impoundment. However, Sculthorpe further states that in natural situations, temperature at a given site does not appreciably affect the distribution of a species within that site. Owing to the fact that increased temperatures from the plant discharge are not a *natural* phenomencn, temperature must be considered.

Temperature effects on vascular vegetation have received increased attention in recent years (Grace and Tilly, 1975; Sharitz et al., 1974a; Sharitz et al., 1974b, Parker et al., 1973; and Anderson, 1969). The effects have been varied. Increased growth has been noted with elevated temperature. Changes in species composition and the elimination of some species in heated areas have been observed. Seasonal biomass peaks have occurred earlier in the growing season and flowering of some species has been enhanced or eliminated. At temperatures above 45°C (113°F), death of vegetation has been reported.

Pond C of the Par Pond system at the Savannah River Plant, noted in a study by Parker et al. (1973), reaches a maximum temperature of 50°C (122°F) and remains above 45°C (113°F) for much of the year. Vegetation does exist in Pond C but is significantly less than that of adjacent areas in which ambient temperatures range from 10°C (50°F) to 30°C (86°F). These authors consider temperature to be the primary criterion in evaluating the distribution of vegetation in the Par Pond system. Grace and Tilly (1975) have studied temperature related competition. Najas guadalupensis overtakes Myriophyllum spicatum at the "hot" station. Their "hot" station has an average maximum temperature of 33.4°C (93.9°F). Stanley (1970), also studying Myriophyllum spicatum, reveals that photosynthesis increases with temperature up to 35°C (95°F). At that point the depth to which colonies will become established is restricted. Stanley also found the optimum pH for growth of M. spicatum to be 8.5 - 9.0. The average pH value for the Robinson Impoundment is near 5.3.

In studies of other aquatic species Wilkinson (1963) indicates that the optimal temperature range for growth of waterstargrass (Heteranthera dubia) and coontail (Ceratophyllum demersum) to be 25°C (77°F) and 30°C (86°F), respectively, and that Vallisneria spiralis grows best at 33°C (91°F) to 36°C (97°F). Anderson (1969) reports a high temperature tolerance for coontail of 50°C (122°F). Anderson's study, which dealt primarily with the respiration rates of pondweed (Potamogeton perfoliatus), revealed that the plants are capable of some physiological adjustment to elevated temperatures up to 45°C (113°F). The respiration rate of Potamogeton perfoliatus was found to increase in the ranges studies 25°C (77°F) to 45°C (113°F). Yarwood (1961) has also investigated acquired heat tolerance in plant leaves. He has demonstrated adaptations to temperatures as high as 55°C (131°F).

7.3 Summary and Conclusions

It can be generalized from the literature reviewed that detrimental temperature effects may become apparent near 35°C (95°F). However, damaging temperatures and their effects vary among species. Monthly thermal sampling at the Robinson Impoundment has shown that surface temperatures have not exceeded 35°C (95°F) below Transect CA or above Station F during 1975 and below Transect D or above the bridge during 1974. At the 3' depth, 35°C (95°F) has been exceeded at Transect D in 1975 but not in 1974, similarly for the 6' depth. Table 7.3.1 presents maximum temperatures found at the various transects (Figure 7.1.1) at the Robinson Impoundment during 1974 and 1975. Other pertinent temperature data is available from Section 3.3 and Exhibit 2.1.

Referring to the map (Figure 7.2.1 through Figure 7.2.4), no significant difference in the overall species distribution could be discerned from the dam to the SR 346 bridge, except those caused by substrate and turbulence. Nevertheless, the area near the immediate discharge would be expected to support somewhat more extensive populations of aquatic macrophytes without the thermal effluent from the Robinson Plant. Small mats of Eleocharis baldwinii have been found in this area during the winter months, but apparently its vegetative shoots die back due to elevated temperatures during the summer. However, the rootstock remains alive and reestablishes active growth during cooler periods.

Areas in which the thermal effluent restricts the growth of aquatic plants occur in the protected coves on the eastern shore opposite the discharge canal and in the coves directly north of the canal. These areas provide necessary habitat for colonization of aquatic plants. Wind caused turbulence is moderate; the substrate contains some silt and organic material, and the bottom slopes gradually away from the shores, providing an expanse of shallow water. Figures 7.3.1 and 7.3.2 illustrate areas of possible reduced aquatic macrophyte growth due to the thermal effluent from the Robinson Plant. Surface temperatures in this region reached 40.4°C (105°F) in July of 1975 and 37.8°C (100°F) in July of 1974 on the discharge side of the impoundment and 38.9°C (102°F) in July of 1975 and 36.5°C (98°F) in July of 1974 on the side opposite to the discharge canal. From a fisheries standpoint, areas of aquatic macrophytes are important in providing a spawning medium, shelter, and food sources, and any additional areas of macrophytic growth would be of value.

It is felt that the vegetation in the lower part of the impoundment represented in Figures 7.2.1 and 7.2.2 is not limited by the thermal effluent from the Robinson Plant. Increased growth due to elevated temperatures up to 35°C (95°F) would probably not be apparent because the low nutrient content of the impoundment is an important limiting factor. As previously mentioned, turbulence, substrate, and the physiographic and man-made features (illustrated on Figures 7.2.1a - 7.2.3a) are primary reasons for the reduction of the amount of aquatic vascular vegetation in unprotected areas of the impoundment.

Above the SR 346 bridge (Figure 7.2.4), an abrupt change in vegetation is apparent. Substrate and reduced wave action increase the suitability of this area for colonization by macrophytes. Except when strong southerly winds force heated water under the bridge, very little, if any, thermal addition is made to this area by the plant discharge. There are no identifiable effects of the thermal effluent from the Robinson Plant in this area.

On Black Creek below the impoundment, shading of the channel by the tree canopy, steepness of the banks, and low nutrient content are important factors governing submerged, floating, and emergent aquatic macrophytes. Maximum temperatures at Stations H and K along Black Creek, 32.9°C (90°F) and 31.8°C (88°F) are not adverse to the vegetative communities found here.

In considering the entire impoundment, the limited areas which are thermally influenced from the standpoint of aquatic macrophytes do not pose a threat to the protection of a balanced and indigenous community of shellfish, fish, and wildlife in and around the impoundment.

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Table 7.1.1 Importance of some genera of aquatic plants in the Robinson Impoundment for fish, birds, and mammals.*

		Important to Fish as		As Food for Birds					As Food for Mammals	
		** Food Producer	Shade & Shelter	Ducks	Coots & Geese, etc.	Grebes & Swans, etc.	Marsh Birds (waders)	Game Birds	Beaver	Muskrat
Brasenia, Carex, Nuphar, Nymphaea, Nymphoides Sparganium	Fruits & Seeds			0	0	0	0	0		0
	Foliage	0	0							
	Rhizomes & Tubers								0	0
Saggittaria, Scirpus, Cyperus	Fruits & Seeds			X	X	X		0		
	Foliage	0	0		0	0				
	Rhizomes & Tubers								X	X
Typha	Fruits & Seeds			0						
	Vegetative Parts	0	0							X
Utricularia	Whole Plants	0	0							
Myriophyllum, Proserpinaca, Potamogeton	Foliage	X	X							
	Fruits & Seeds			X	X	X	X	X		

0 - Denotes moderate importance
X - Denotes primary importance

*Adapted from Sculthorpe (1967)
**Attached macroinvertebrates

Table 7.1.2 Robinson Impoundment aquatic vegetation important* as a wildlife food sources**

Fauna	*Typha*	*Sparganium*	*Potamogeton*	*Sagittaria*	*Cyperus*	*Scirpus*	*Eleocharis*	*Peltandra*	*Brasenia*	*Nymphaea*
Muskrat	X	X								
Wood Duck								X		X
Mallard		X	X	X	X	X	X			
Black Duck		X				X	X			
Redhead		X								X
Ruddy Duck		X				X				
Whistling Swan		X	X				X			
Gadwall		X	X			X				
Canada goose							X			
Ring-necked Duck		X	X			X	X		X	X
American Coot		X					X			
Lesser Scaup		X								X
Blue-winged Teal					X		X			X
Green-winged Teal					X	X				
King Rail							X			

*Comprises greater than 2% of food in the Southeast.
**Source: Martin et al., 1951.

Table 7.2.1 Plant species collected and/or observed in and near the Robinson Impoundment during 1974 and 1975.

Family	Species	Common Name
Lycopodiaceae	Lycopodium appressum*	Southern Bog Clubmoss
Osmundaceae	Osmunda regalis var. spectabilis*	Royal Fern
Blechnaceae	Woodwardia virginica*	Virginia Chain-Fern
	W. areolata*	Netted Chain-Fern
Pinaceae	Pinus elliottii	Slash Pine
	P. palustris	Longleaf Pine
	P. taeda	Loblolly Pine
Taxodiaceae	Taxodium distichum*	Bald Cypress
Cupressaceae	Chamaecyparis thyoides*	Atlantic White Cedar
	Juniperus virginiana	Eastern Red Cedar
Typhaceae	Typha latifolia*	Cat-tail
Sparganiaceae	Sparganium americanum*	Bur-reed
Potamogetonaceae	Potamogeton diversifolius*	Pondweed
Alismataceae	Sagittaria engelmanniana*	Arrowhead
	S. graminea*	Arrowhead
	S. latifolia*	Wapato
Poaceae	Arundinaria gigantea*	Cane
	Arundo donax*	Giant Reed
	Aristida stricta	Wire Grass
	Andropogon virginicus	Broomsedge
	Panicum hemitomon	Panicum
Cyperaceae	Carex lurida*	Sedge
	Cyperus sp.*	Sedge
	Scirpus cyperinus*	Bulrush
	S. etuberculatus*	Bulrush
	Dulichium arundinaceum*	Dulichium
	Eleocharis equisitodes*	Spike-rush
	E. baldwinii*	Spike-rush
	E. quadrangulata*	Spike-rush
	E. obtusa*	Spike-rush
Araceae	Orontium aquaticum*	Golden Club
	Peltandra virginica*	Peltandra
Mayacaceae	Mayaca fluviatalis*	Bog Moss
Xyridaceae	Xyris sp.*	Yellow-eyed Grass

Family	Species	Common Name
Eriocaulaceae	Eriocaulon compressum*	Pipewort
Commelinaceae	Commelina erecta	Dayflower
Juncaceae	Juncus canadensis*	Juncus
	J. effusus*	Juncus
	J. polycephalus*	Juncus
	J. repens*	Juncus
Liliaceae	Allium sp.	Wild Onion
	Hemerocallis fulva	Day lily
	Smilax bona-nox*	Greenbrier
	Yucca filamentosa	Bear-grass
Haemodoraceae	Lachnanthes caroliniana*	Redroot
Iridaceae	Iris virginica*	Blue Flag Iris
	I. tridentata*	Iris
Orchidaceae	Pogonia ophioglossoides*	Rose Pogonia
Salicaceae	Salix nigra*	Black Willow
	Populus heterophylla*	Swamp Cottonwood
Myricaceae	Myrica cerifera*	Wax Myrtle
	M. heterophylla*	Bayberry
Juglandaceae	Carya tomentosa	Mockernut Hickory
Betulaceae	Alnus serrulata*	Tag Alder
Fagaceae	Quercus incana	Upland Willow Oak
	Q. coccinea	Scarlet Oak
	Q. falcata	Southern Red Oak
	Q. laurifolia*	Laurel Oak
	Q. phellos*	Willow Oak
	Q. nigra*	Water Oak
	Q. marilandica	Blackjack Oak
	Q. margaretta	Scrubby Post Oak
	Q. laevis	Turkey Oak
	Q. stellata	Post Oak
Moraceae	Morus rubra	Red Mulberry
Loranthaceae	Phoradendron serotinum	Mistletoe
Polygonaceae	Rumex acetosella	Sheep-sorrel
	Polygonum hydropiperoides	Polygonum
Phytolacaceae	Phytoloacca americana	Poke Weed
Nymphaeaceae	Nuphar luteum*	Spatter-dock
	Nymphaea odorata*	Water-lily
Cabombaceae	Brasenia schreberi*	Water Shield
	Cabomba caroliniana*	Fanwort

Table 7.2.1 continued

Family	Species	Common Name
Magnoliaceae	*Magnolia grandiflora*	Southern Magnolia
	*M. virginiana**	Sweet Bay
	Liriodendron tulipifera	Tulip Tree
Lauraceae	*Persia borbonia*	Red Bay
	Sassafras albidum	Sassafras
	*Lindera benzoin**	Spice Bush
Sarraceniaceae	*Sarracenia flava**	Yellow Pitcher-plant
	*S. rubra**	Sweet Pitcher-plant
Droseraceae	*Drosera intermedia**	Sundew
Saxifragaceae	*Itea virginica**	Virginia Willow
Hamamelidaceae	*Liquidambar styraciflua**	Sweet Gum
Rosaceae	*Rubus* sp.*	Blackberry
	Crataegus sp.	Hawthorn
	Prunus serotina	Black Cherry
	*Sorbus arbutifolia**	Red Chokeberry
Fabaceae	*Baptisia cinerea*	Baptisia
	Albizia julibrissin	Mimosa
	Desmodium sp.	Beggar Lice
Geraniaceae	*Geranium* sp.	Cranesbill
Meliaceae	*Melia azedarach*	China-berry
Polygalaceae	*Polygala lutea*	*Polygala*
Anacardiaceae	*Rhus copallina*	Winged Sumac
	R. glabra	Common Sumac
	R. radicans	Poison Ivy
Cyrillaceae	*Cyrilla racemiflora**	Leatherwood
Aquifoliaceae	*Ilex opaca*	Holly
Aceraceae	*Acer rubrum**	Red Maple
Vitaceae	*Vitis* sp.*	Grape
Theaceae	*Gordonia lasianthus**	Loblolly Bay
Hypericaceae	*Hypericum reductum*	St. John's-wort
	H. stans	St. Peter's-wort
Melastomataceae	*Rhexia virginica*	Meadow Beauty

Table 7.2.1 continued

Family	Species	Common Name
Onagraceae	Oenothera sp.	Evening Primrose
Haloragaceae	Myriophyllum pinnatum*	Myriophyllum
	Proserpinaca pectinata*	Proserpinaca
Apiaceae	Hydrocotyle umbellata*	Marsh Pennywort
Nyssaceae	Nyssa sylvatica*	Black Gum
	N. sylvatica var. biflora*	Black Gum
Cornaceae	Cornus florida	Dogwood
Clethraceae	Clethra alnifolia*	Sweet Pepperbush
Ericaceae	Vaccinium arboreum*	Sparkleberry
	V. corymbosum	Highbush Blueberry
	V. atrococcum	Black Highbush Blueberry
	Leucothoe racemosa*	Fetter-bush
	Gaylussacia sp.	Huckleberry
	Lyonia lucida*	Fetter-bush
	Diospyros virginiana	Persimmon
Styracaceae	Styrax americana*	Storax
Gentianaceae	Gentiana atumnalis	Pine-Barren Gentian
	Nymphoides cordata*	Floating Heart
	Sabatia angularis	Rose Pink
Solanaceae	Solanum sp.	Horse Nettle
Bignoniaceae	Anisostichus carpreolata*	Cross Vine
Lentibulariaceae	Utricularia biflora*	Bladderwort
	U. inflata*	Bladderwort
Rubiaceae	Cephalanthus occidentalis*	Button Bush
Caprifoliaceae	Viburnum nudum*	Viburnum
	Lonicera sempervirens	Coral Honeysuckle
	L. japonica*	Japanese Honeysuckle
	Sambucus canadensis	Elderberry
Campanulaceae	Lobelia glandulosa	Lobelia
Asteraceae	Aster	Aster
	Chrysanthemum sp.	Chrysanthemum
	Helenium sp.	Sneeze-weed
	Eupatorium aromaticum	Thoroughwort
	Liatris earlei	Blazing Star

*Denotes true aquatic species and species found to occur in intermittently or seasonally flooded areas

Table 7.3.1. Maximum average[1] temperatures recorded[2] in 1974 and 1975.

		1974 °C	1974 °F	1975 °C	1975 °F
Transect A	Surface	31.1	88	33.4	92
	3'	31.1	88	33.4	92
	6'	31.1	88	33.4	92
Transect B	Surface	31.1	88	33.4	92
	3'	31.1	88	33.4	92
	6'	31.1	88	32.8	91
Transect C	Surface	32.2	90	34.5	94
	3'	32.2	90	33.9	93
	6'	32.2	90	32.8	91
Transect CA[3]	Surface	--	--	35.0	95
	3'	--	--	33.9	93
	6'	--	--	32.8	91
Transect D	Surface	33.9	93	35.6	96
	3'	34.5	94	35.6	96
	6'	33.9	93	35.0	95
Transect E[4]	Surface	37.8	100	40.4	105
	3'	37.8	100	39.5	103
	6'	37.8	100	36.1	97
Station F[5]	Surface	32.8	91	34.5	94
	3'	32.2	90	33.4	92
	6'	31.1	88	30.0	86
Station G	Surface	31.7	89	31.7	89
	3'	28.9	84	28.9	84
	6'	25.0	77	27.2	81

Notes

1. Transect values are the average of three stations at each Transect.

2. Maximum for the year, taken at monthly sampling intervals.

3. Not recorded in 1974.

4. Temperatures at Station 3 of Transect E which is 200' from the point of discharge reached 39.0°C (102°F) in 1974 and 41.5°C (107°F) in 1975.

5. One reading taken for each depth at Stations.

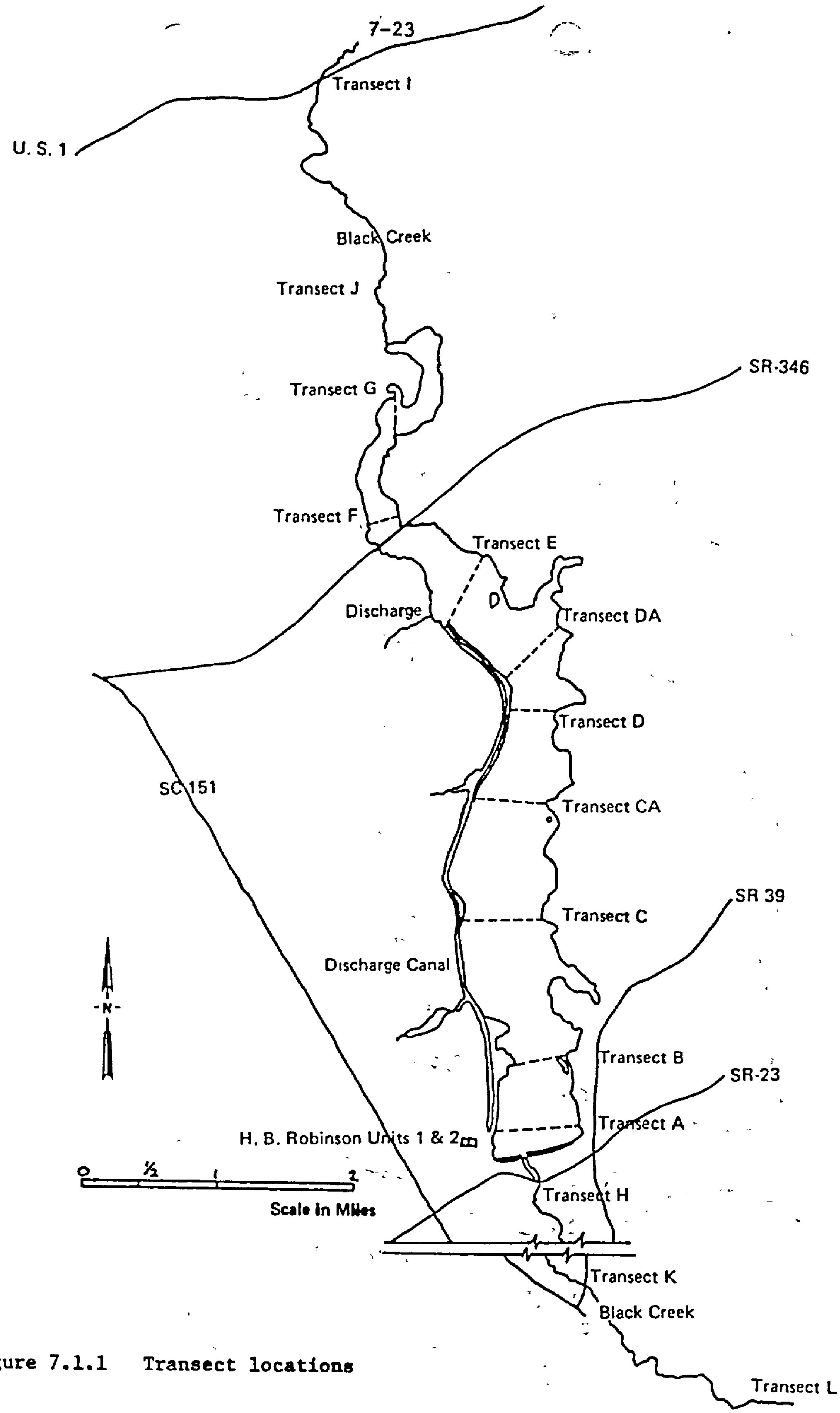
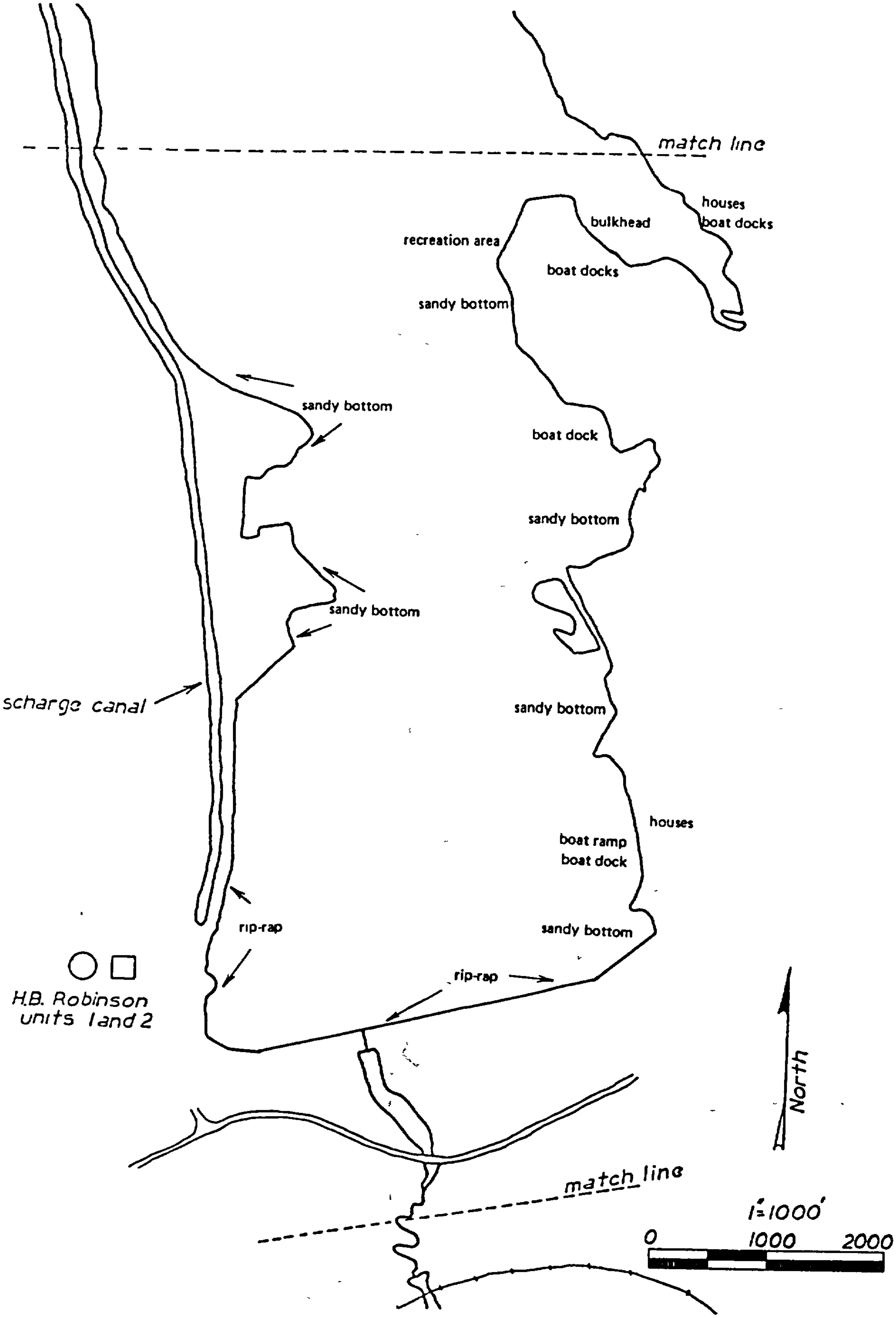


Figure 7.1.1 Transect locations



gure 7.2.1a Physiographic and man-made features which influence the distribution of uatic vegetation

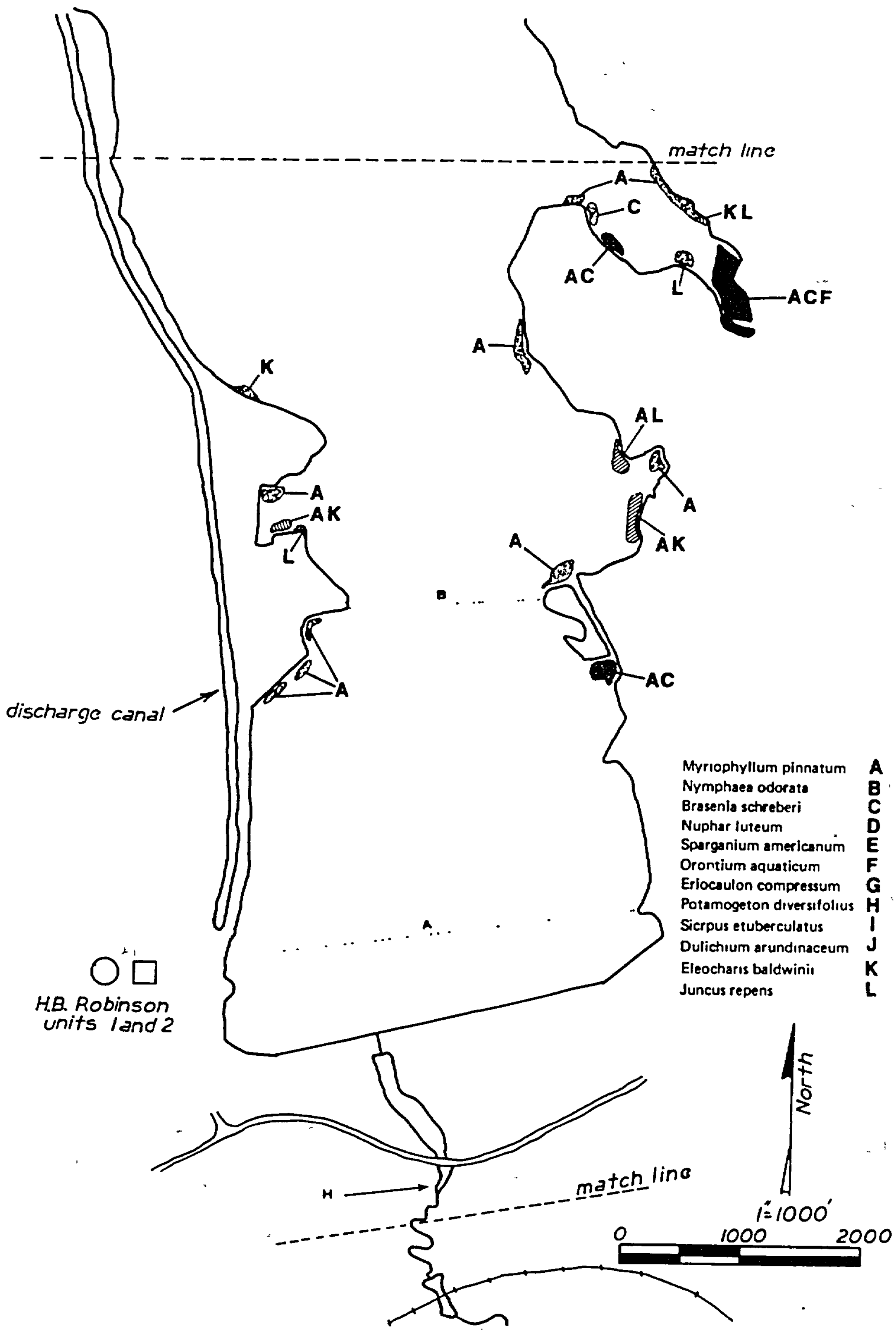
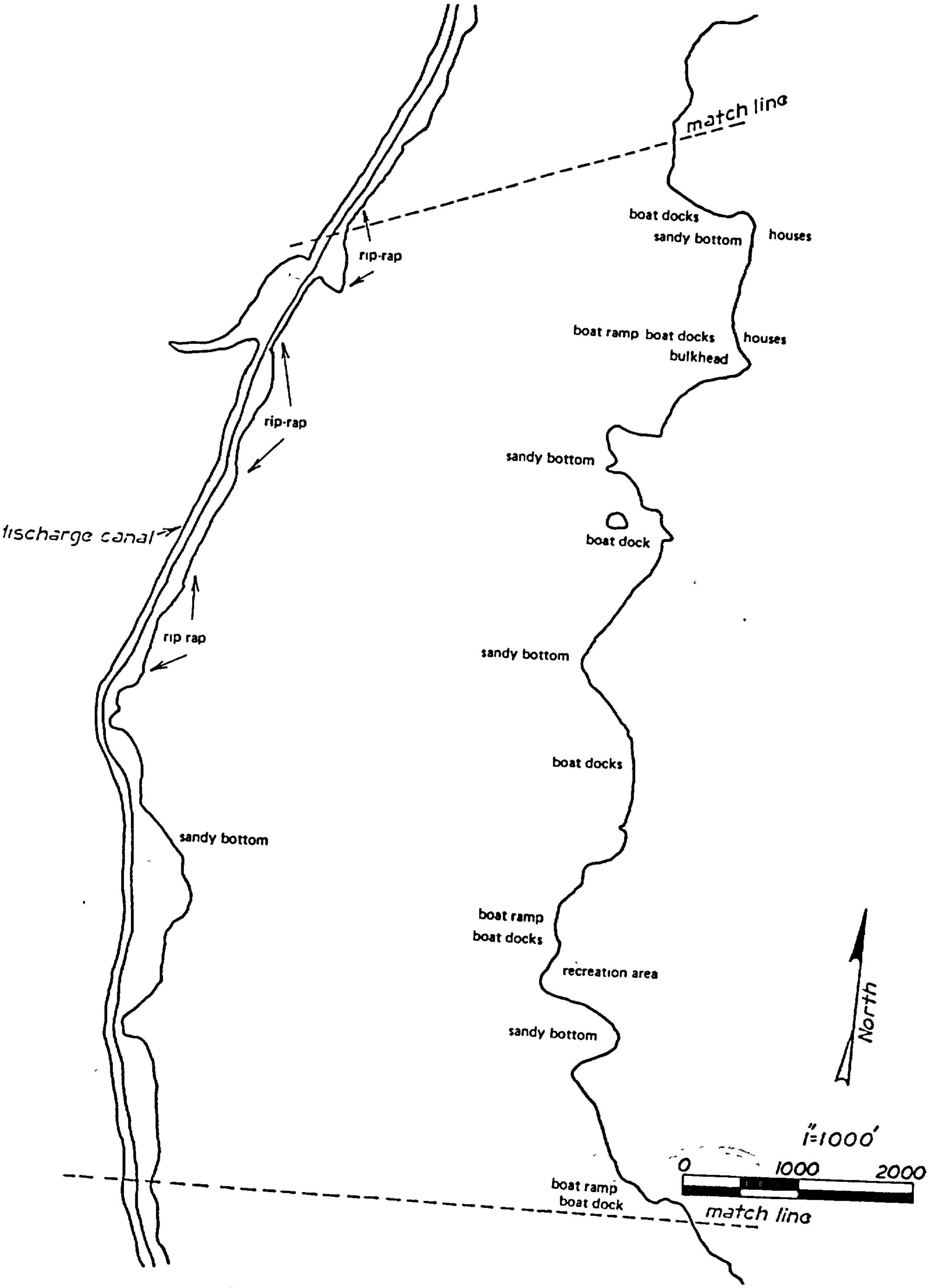


Figure 7.2.1 Vegetational distributions



gure 7.2.2a Physiographic and man-made features which influence the distribution of
atic vegetation

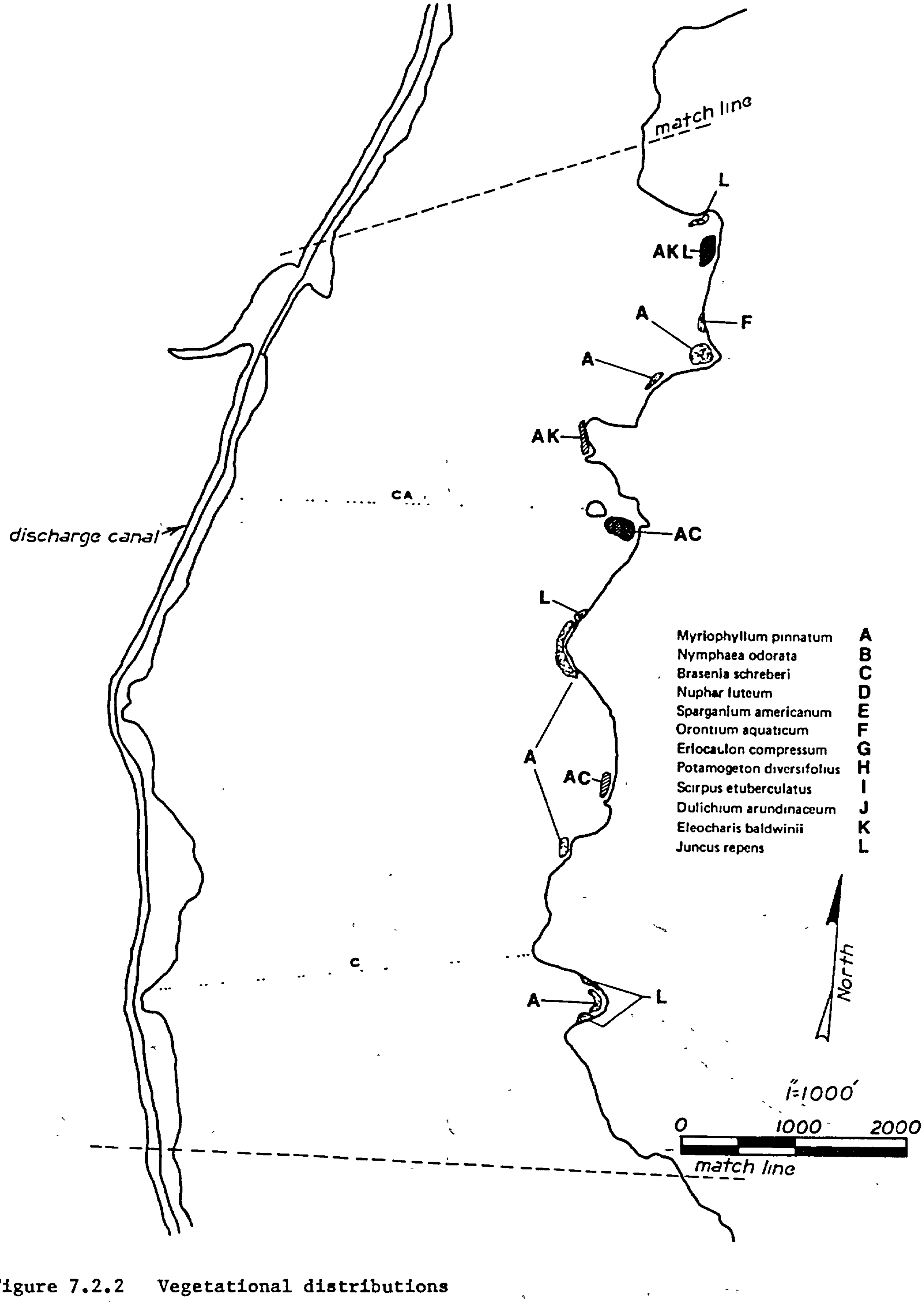


Figure 7.2.2 Vegetational distributions

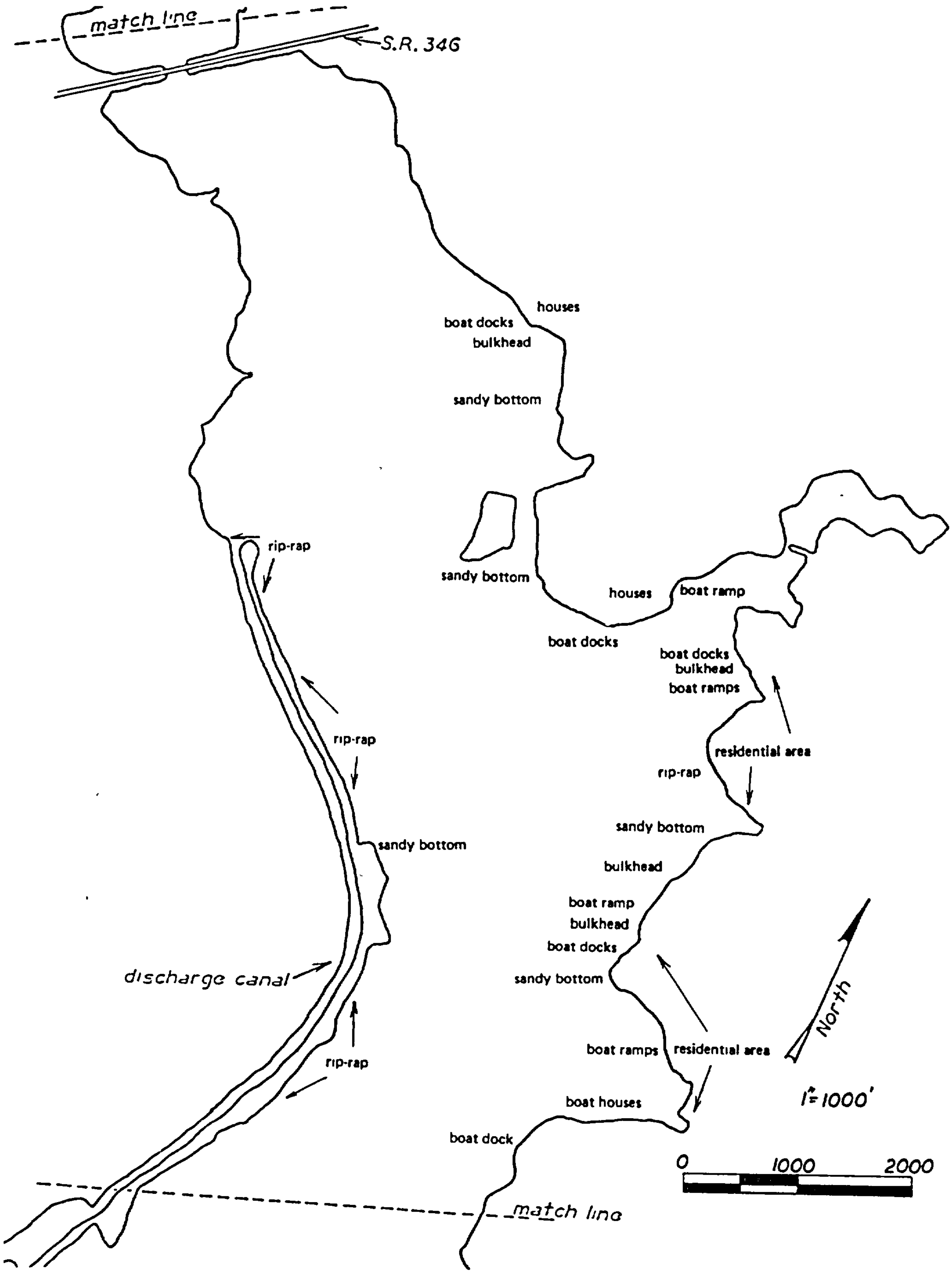


Figure 7.2.3a Physiographic and man-made features which influence the distribution of aquatic vegetation

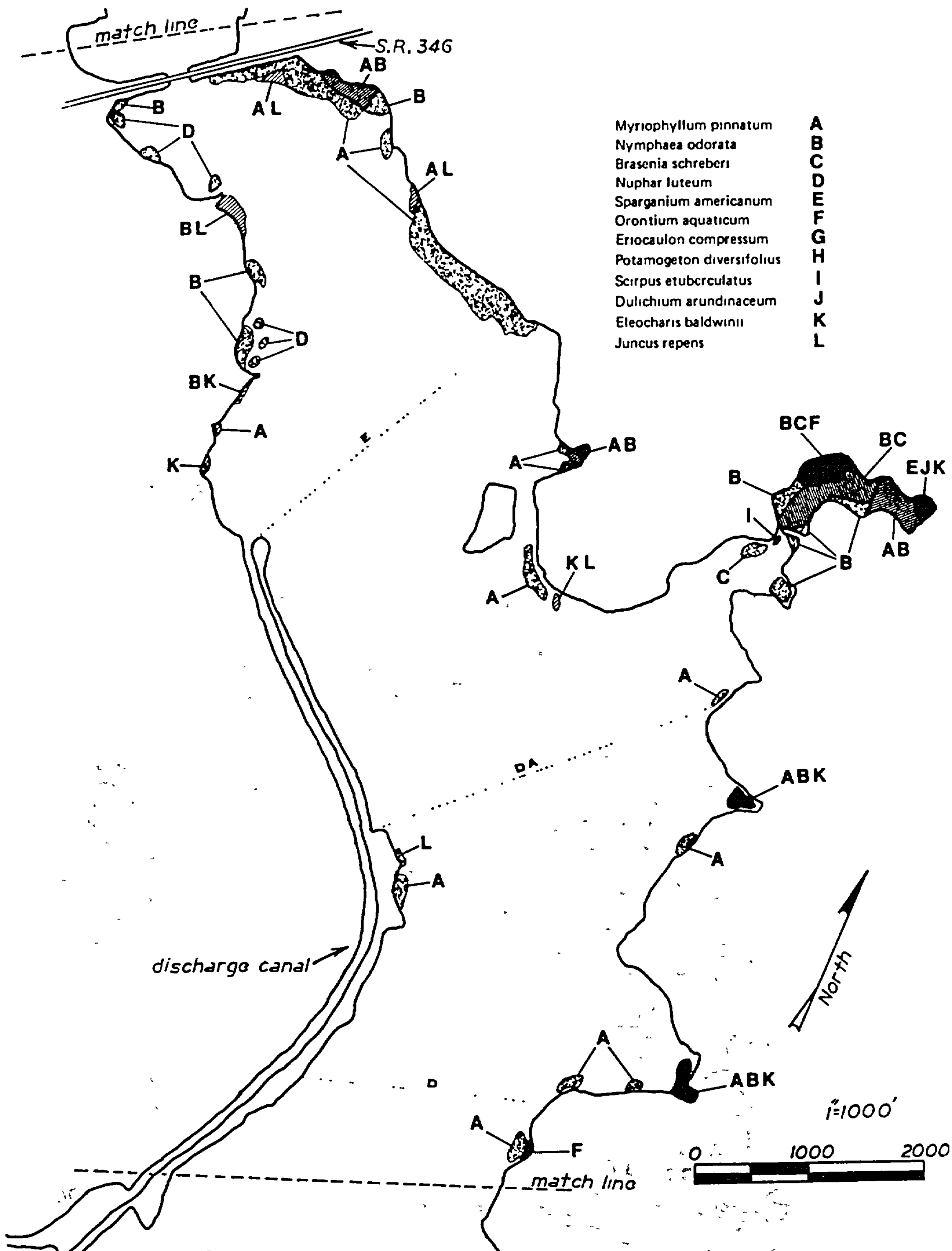


Figure 7.2.3 Vegetational distributions

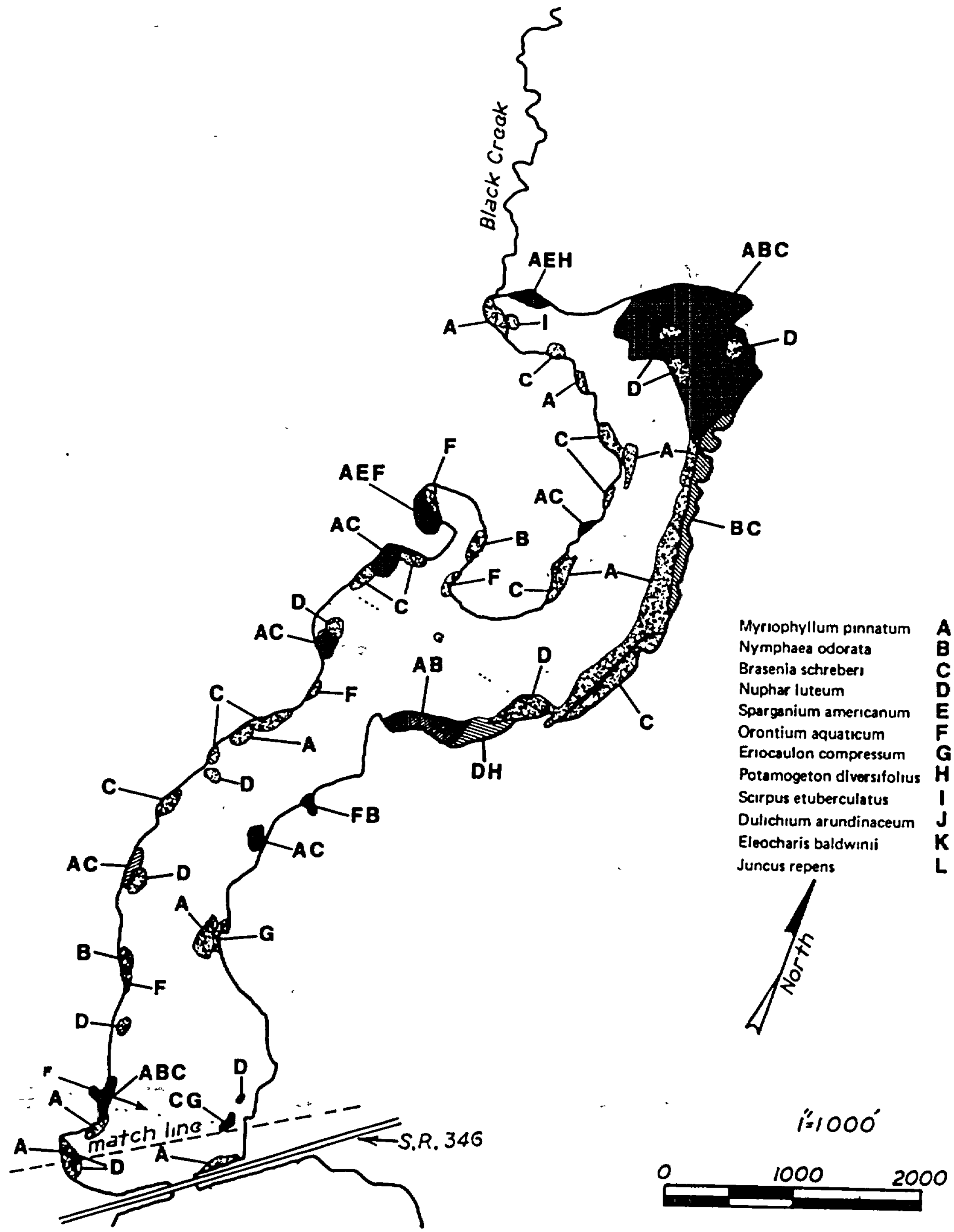


Figure 7.2.4 Vegetational distributions

Figure 7.2.5 Rip-rap along discharge canal above Transect A showing scattered red maple along shore

Figure 7.2.6 Sandy area near Transect A and rip-rap on dam in background

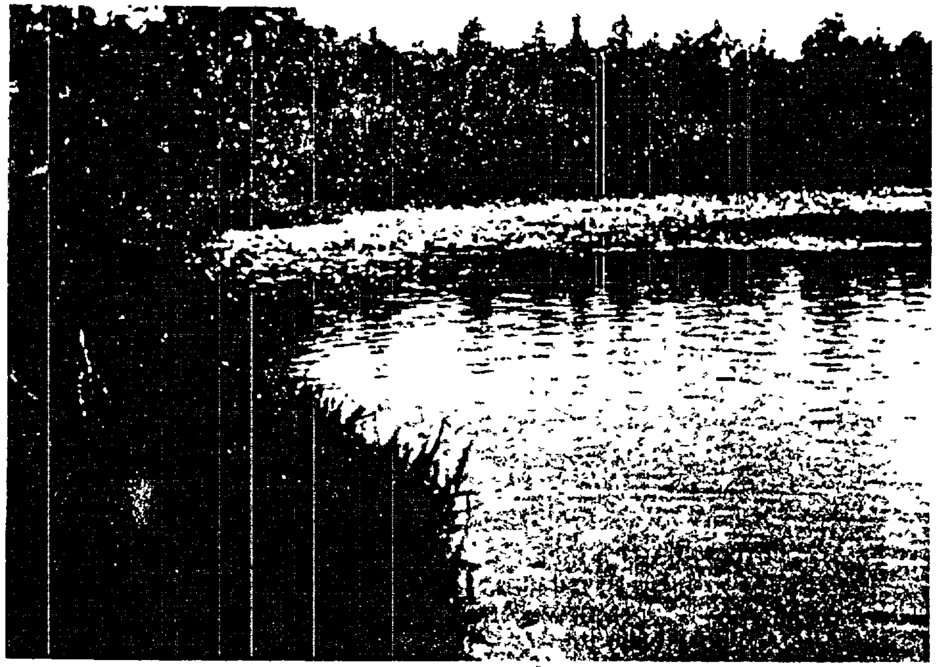


Figure 7.2.7 Cove approximately 2000' north of mouth of discharge canal showing flowering Nymphaea and Nuphar

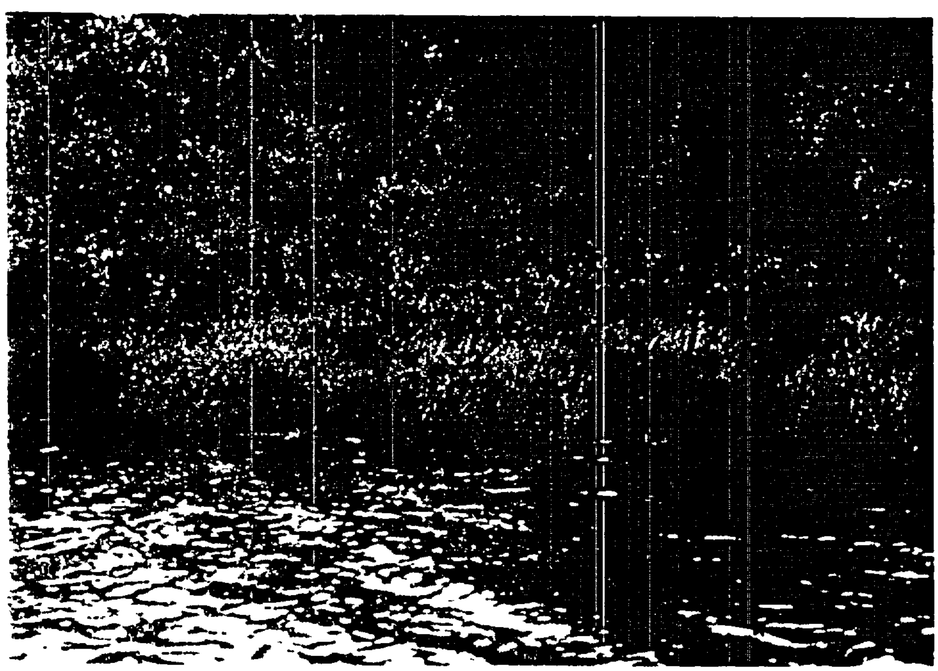


Figure 7.2.8 Shoreline vegetation illustrating Panicum hemitomon and lowland species with Sandhills vegetation rising in the background

Figure 7.2.9 Upper impoundment below Station J showing Scirpus, Nuphar, and Brasenia with other marsh vegetation in background

Figure 7.2.10 Gum, cypress, and associated swamp hardwoods at Black Creek Station K

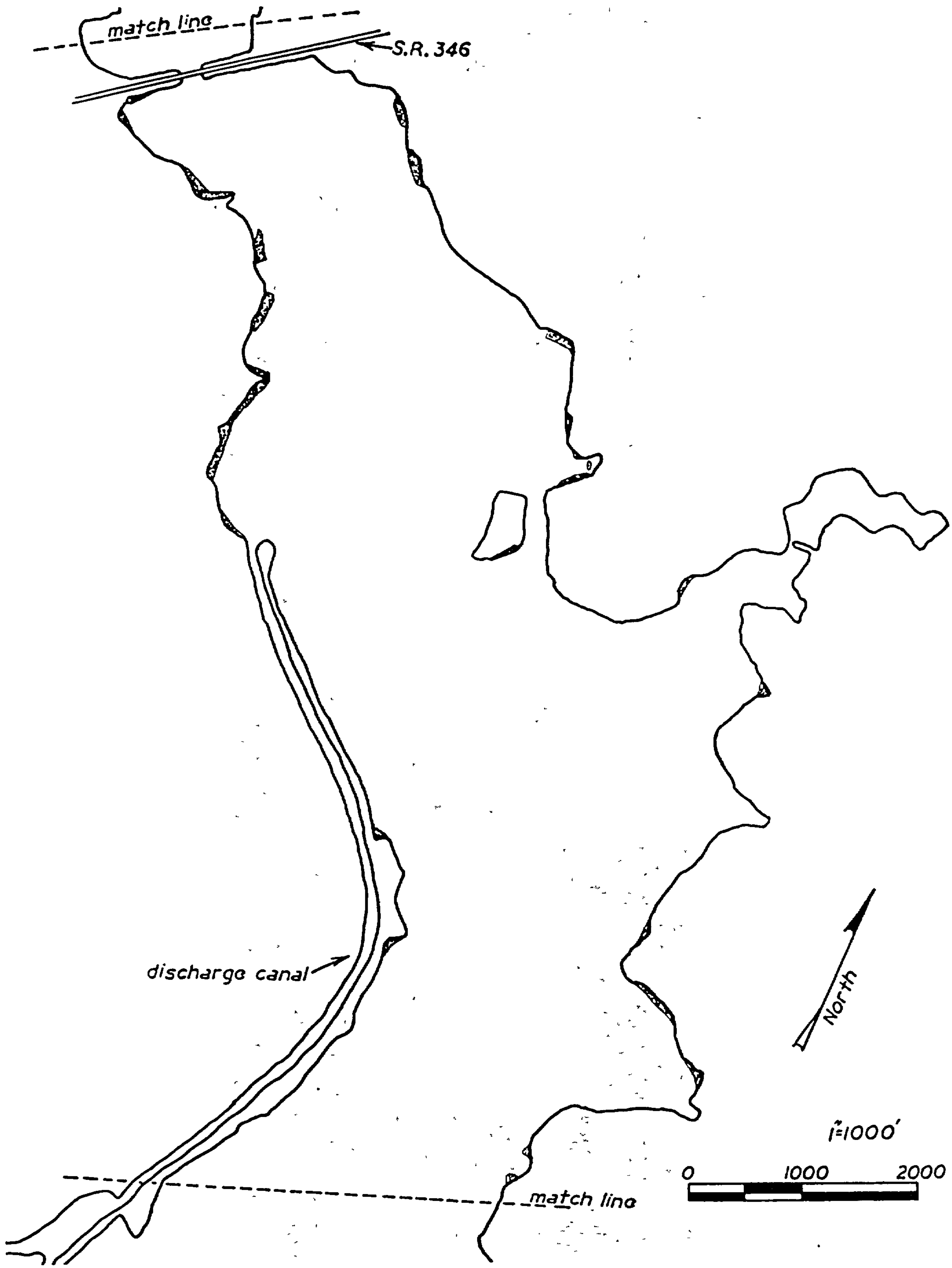


Figure 7.3.1 Areas of reduced aquatic macrophyte growth due to the thermal effluent from the Robinson Plant

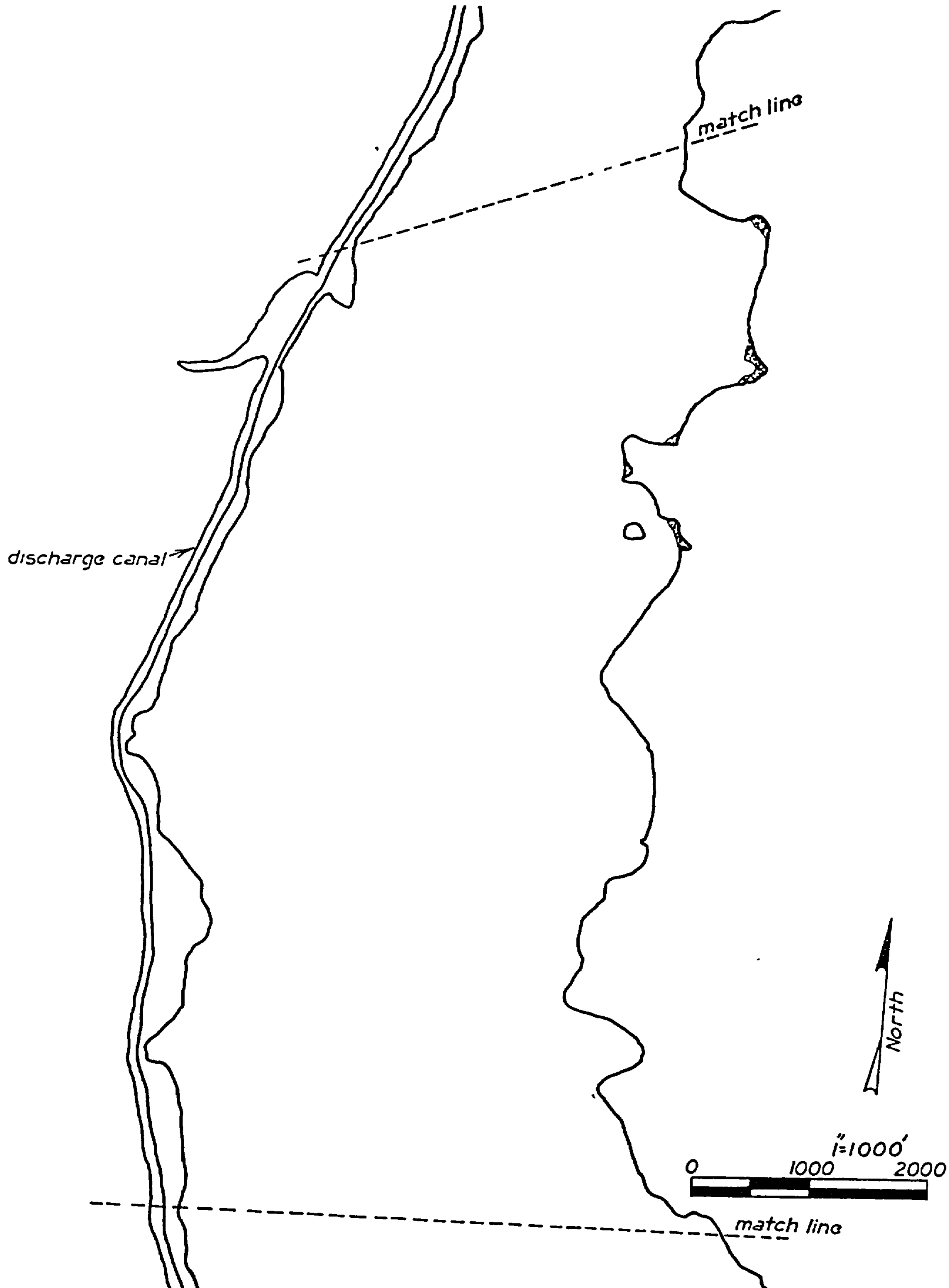


Figure 7.3.2 Areas of reduced aquatic macrophyte growth due to the thermal effluent from the Robinson Plant

8.0 Terrestrial Vertebrate Zoology

8.1 Introduction

When considering the effects of heat on the capacity of Robinson Impoundment to support a balanced indigenous community of fish, shellfish, and wildlife, account must be taken of the interactions which exist between the terrestrial and amphibious fauna and the aquatic ecosystem. These interactions have been evaluated by means of a terrestrial vertebrate sampling program at Robinson Impoundment. The objectives of the program were to identify the species which are dependent on the aquatic ecosystem, define the nature and extent of dependence, and determine the effects, if any, of thermally induced changes in the aquatic system on the identified species. Sampling, to achieve those objectives, was initiated in August, 1974, and continued on a quarterly schedule through February, 1976. Beginning July, 1975, through May, 1976, a special monthly study was conducted to determine what effects, if any, the heated effluent had on amphibian reproduction.

8.2 Amphibians

8.2.1 Methods

Because amphibians exhibit a high degree of dependence on an aquatic ecosystem, special emphasis was placed on identifying the amphibian species, distributions, and reproductive activities at Robinson Impoundment and Black Creek. Data on amphibians were obtained using three methods.

First, a monthly systematic effort was directed at the collection and identification of larval amphibians from selected locations within the study area. Thirteen stations (Figure 8.2.1) were located in suitable habitat in both the heated (MHS-5 to 9) and unheated (MHS-10 to 13) portions of the impoundment, in an outpocket of the discharge canal (MHS-4), and in Black Creek below the impoundment (MHS-1 to 3). The stations in the heated portion of the impoundment were restricted to the area between Transects DA and F where the greatest thermal stress was expected and where appropriate habitat was available. Very little shoreline habitat suitable for amphibian reproduction existed south of Transect DA (Figures 7.2.1 to 7.2.4 and 7.2.1a to 7.2.3a). Hand held dip nets were used to collect specimens. One man-hour of effort was expended monthly at each station. Water temperatures were measured and recorded at the stations during each sampling period.

Second, an evening frog and toad call survey was conducted in conjunction with the monthly larval amphibian sampling. A minimum of five minutes was spent at each of eight stations (Figure 8.2.1) during which time any calling frogs and toads were identified. Four stations were located in heated areas of the impoundment between Transects DA and F (MHC-4 to 7), one in an unheated area north of Transect F (MHC-8), and three in Black Creek south of the impoundment (MHC-1 to 3). As with the larval sampling stations, no call survey stations were located south of Transect DA due to the limited amount of appropriate habitat available there.

Third, general observations and collections of specimens were made during all phases of terrestrial, aquatic, and fishery sampling throughout the impoundment area and at Black Creek. Collected specimens were preserved in 10% formalin, returned to the laboratory for positive indentification, cataloged, and retained in a reference collection. Essential details of all observations and collections were coded on computer data cards to facilitate data sorting and analysis.

8.2.2 Results and Discussion

Species Observed

Twenty-two amphibian species representing twelve genera were identified within the study area. Seven of those species were found only at Robinson Impoundment while three others were observed only at Black Creek. A total of nineteen and fifteen species were reported from the impoundment and Black Creek, respectively. A species list is presented in Table 8.2.1.

Observed Distribution

The observed distribution of each species was summarized geographically and thermally. Table 8.2.2 shows the distribution of observations and collections of each species from four regions of the study area. Those regions were Black Creek south of the impoundment, the impoundment north of Transect F, the impoundment south of Transect F, and the discharge canal (Figure 8.2.1). Since sampling effort was not equal among the four regions, no conclusions were possible concerning the relative abundance of the species in those regions. Table 8.2.3 reports water temperature means and ranges associated with both larval and adult specimens of the species collected or observed. Comparisons between the observed temperature data and the thermal tolerances reported in the literature are discussed in the sections entitled: Thermal Effects on Distribution and Thermal Effects on Reproduction, Development, and Growth.

Of the twenty-two identified amphibian species, only the southern two-lined salamander (Eurycea bislineata), the southern toad (Bufo terrestris), the southern cricket frog (Acris g. gryllus), the bullfrog (Rana catesbeiana), and the southern leopard frog (Rana utricularia) were found in all four regions of the study area. However, seven other species, including the lesser siren (Siren i. intermedia), the dwarf waterdog (Necturus punctatus), the mud salamander (Pseudotriton montanus), the spring peeper (Hyla crucifer), the green treefrog (Hyla cinerea), the carpenter frog (Rana virgatipes), and the bronze frog (Rana clamitans), occurred in all regions except the discharge canal. The little grass frog (Limnaoedus ocularis) was observed at the impoundment both north and south of Transect F. Of particular significance was the fact that five species; the dusky salamander (Desmognathus fuscus), the red salamander (Pseudotriton ruber), the American toad (Bufo americanus), the Fowler's toad (Bufo woodhousei fowleri), and the squirrel treefrog (Hyla squirrella); were observed at the thermally affected portion of the impoundment south of Transect F but not at the thermally unaffected portion of the impoundment north of Transect F. Only one species was found in the cooler upper impoundment that did not occur in at least one of the other regions of the study area. That species was the northern cricket frog (Acris c. crepitans) which at Robinson Impoundment is near the periphery of its reported range (Conant, 1975). Three additional species; the two-toed amphiuma

(Amphiuma means), the many-lined salamander (Stereochilus marginatus), and the dwarf salamander (Eurycea quadridigitata); were collected only along Black Creek south of the impoundment.

Dependence on the Aquatic Ecosystem

The specific nature and extent of dependence on the aquatic ecosystem are quite different for each of the identified species. Some remain in or closely associated with water throughout their life cycles. Others return to water only during their respective breeding seasons. Nevertheless, appropriate and adequate breeding sites, cover, food, and water temperatures within tolerable ranges are needs common to all species encountered at the impoundment or Black Creek. Each of those needs was considered subject to possible thermal influence.

Amphibians are largely dependent on the heat in the environment to maintain body temperatures at levels which enable the continuance of normal metabolic functions and behavioral activities. Since amphibians have little or no physiological and only limited behavioral means of thermoregulation, environmental temperatures above or below the tolerable range of each species threaten the survival of individuals, and thus the continued existence of the species at the study area.

The reproductive phase of the life cycles of all amphibians found in the study area occurs in or near water, and aquatic plants provide the necessary breeding sites for many of those species (Bishop, 1943; Wright and Wright, 1949). Eggs are often laid attached to or among aquatic vegetation such as found in the shallow areas of the impoundment and Black Creek (Figures 7.2.1 to 7.2.4). Larval stages depend on the vegetation for protective cover during the subsequent period of growth and development. Following metamorphosis, the adults of those species which remain at the impoundment or Black Creek continue to utilize the vegetation for cover. Adults of the more terrestrial species of salamanders, frogs, and toads may no longer depend on the aquatic ecosystems of the study area until the following breeding season.

Anuran food habits range from entirely herbivorous tadpoles to strictly carnivorous adults. Both adult and larval salamanders are completely carnivorous (Goin and Goin, 1962). Thus, aquatic vegetation provides a direct source of food for the herbivorous tadpoles and an indirect source for the carnivorous larvae and adults which prey upon invertebrate and small vertebrate species associated with the vegetation.

Thermal Effects on Distribution

Thermal requirements and tolerances differ among the amphibian species as well as between the larval and adult stages of each species. Experimentally determined values for adult and larval critical thermal maxima (CTM), adult maximum voluntary temperatures (MVT), maximum temperatures for larval development, and maximum embryonic temperature tolerances have been reported in the literature. Values available for the species found within the study area are presented in Table 8.2.4.

Comparison of observed water temperature data included in CP&L Exhibit 2.1 with available adult CTM and MVT values in Table 8.2.4 indicated that thermal exclusion areas existed within the impoundment during the summer months. However, those thermal exclusion areas were believed to have had little direct effect on the actual distribution of most of the amphibian species. The expected (Bishop, 1943; Wright and Wright, 1949; Conant, 1975) and observed habitat preferences and requirements were responsible for the restriction of most of the amphibian species to the shallow, more heavily vegetated margins of the impoundment. Only specimens of lesser siren and dwarf waterdog were collected or observed away from the shallow waters (>0.5 m) along the immediate shoreline of the impoundment. Observed water temperature means and ranges for collected or observed amphibians (Table 8.2.3) and water temperatures recorded during the larval amphibian study (Table 8.2.5) indicated that, in addition to providing appropriate shoreline habitat, the many tributary springs, seeps, and streams created cool water plumes, marshy areas, and swamps which acted as thermal buffer zones. Those buffer zones protected amphibians occurring there from the encroachment of hotter water during the critical summer months.

The thermal limitation of the distribution and productivity of aquatic plants and associated benthic fauna discussed in Sections 6.0 and 7.0 probably had some indirect influence on the distribution of some of the amphibian species near the point of discharge by reducing the available cover and food supply. The distribution of the two species which inhabited the impoundment waters away from the immediate shoreline (lesser siren and dwarf waterdog) were more likely affected in this way. Because most of the amphibian species occurred exclusively along the shoreline where thermal impact on vegetation and benthos was minimized by the influx of cooler water from tributaries, little impact on the distribution of those species was believed to have resulted.

Thermal Effects on Reproduction, Development and Growth

Thermal impact on amphibian reproduction, development, and growth may occur in a number of ways. The availability of aquatic vegetation which provides breeding sites and food to some species may be limited. The occurrence of suitable prey species required by carnivorous larvae may be reduced. Reproductive behavior may be stimulated outside the normal breeding seasons. The viability of eggs and the survival of larvae may be threatened by temperatures approaching or reaching respective critical thermal tolerances. The rates of embryonic and larval development may be altered.

Breeding habits and requirements of some of the amphibian species found at the study area excluded them from the possible effects of increased heat. The six identified salamander species (Table 8.2.1) required cool water streams, springs, or swamps for egg laying sites and larval nursery areas (Bishop, 1943). Because all collections and observations of both adults and larvae of those six species were made at the mouths of tributaries or in associated marshes and swamps, any expectation of thermal impact on their reproduction, development, or growth was considered unrealistic.

The actual nature and extent of thermal impact on the reproduction, development, or growth of the remaining species was not determined, but some species were more exposed to the elevated water temperatures of the impoundment than others. The entirely aquatic lesser siren and dwarf waterdog were more likely subjected to the effects of increased heat than the other species, but the low number of observations and the lack of life history information made conclusions regarding those species impossible. Few observations of adults and no observations of larvae (Table 8.2.2) made conclusions concerning the American toad, Fowler's toad, northern cricket frog, squirrel treefrog, and little grass frog difficult. However, the location of the study area at or near the periphery of the reported geographical ranges of those five anuran species (Conant, 1975) was more likely responsible for the low number of observations than the effects of heat. The remainder of this discussion centers on the other anuran species (southern toad, southern cricket frog, spring peeper, green treefrog, bullfrog, carpenter frog, bronze frog, and southern leopard frog) listed in Table 8.2.1. The observed distribution of the larvae and breeding calls of those eight anuran species was included in Table 8.2.2.

As was previously discussed for the distribution of the adults of the eight species, the observed distribution of both larvae and calls seemed to be more dependent upon the availability of suitable habitat than on the direct effect of heat. Wright and Wright (1949) indicated that these species lay eggs attached to or among aquatic vegetation found in shallow water areas. Therefore, the thermal limitation of aquatic vegetation near the point of discharge, reported in Section 7.0, probably had some small indirect affect on reproduction, by reducing available breeding sites, and on larval development and growth, by reducing cover and food supply.

Because the larvae of the anuran species found at the impoundment are primarily herbivorous, any effects of heat on the distribution or productivity of benthic invertebrates did not likely produce any measurable effect on the larval development or growth. As previously stated, the carnivorous larvae of the salamander species were restricted by habitat requirements from areas where the benthic productivity was found to be low.

The breeding seasons of frogs and toads are dependent on two thermally influenced factors (Goin and Goin, 1962). First, the animals must be physiologically ready with supplies of ripe ova or sperm. That reproductive readiness is probably controlled by seasonal changes in the activity of the anterior pituitary gland which is known to be influenced by changes in environmental temperature. Second, after breeding condition has been achieved, breeding activity must be induced by appropriate climatic factors which, depending on species, may or may not include a rise in temperature.

A comparison of observed breeding seasons in three regions of the study area for the eight anuran species most likely exposed to the effects of increased heat was made in Table 8.2.6. Breeding calls were considered evidence of breeding season. Data included in the table for the observed breeding months was collected beginning in June, 1975 through May, 1976. During that period some differences were noted between the observed breeding months at the three designated regions. To what degree any of the observed differences were caused by increased water temperatures resulting from the heated discharge was not possible to determine. However, the thermal discharge was expected to be a factor only where differences were observed between the essentially unheated portion of the impoundment north of Transect F and the heated portion of the impoundment south of Transect F. Such differences occurred for four of the eight species (southern cricket frog, bullfrog, bronze frog, and southern leopard frog). The differences in the observed breeding seasons north and south of Transect F were not considered great enough to have had a negative impact on the populations of the respective species.

Available literature values for the thermal tolerances of the eggs and larvae of the amphibians found at the study area are presented in Table 8.2.4. Although water temperatures throughout much of the study area (CP&L Exhibit 2.1) exceeded the reported embryonic and larval tolerance values, the water temperatures recorded during the larval amphibian sampling program (Table 8.2.5) in appropriate breeding habitat indicated availability of water cool enough for successful reproduction throughout the study area. The larvae of only one anuran species, the green treefrog, was found north of Transect F but not south of Transect F. Since only two specimens were collected, that difference was more likely a result of sampling error than a function of thermal stress.

Goin and Goin (1962) reported that higher temperatures accelerate both the embryonic and larval development of amphibians. For the leopard frog (Rana pipiens), hatching occurs in 6 days and metamorphosis in 3 months at 18°C (64°F). At 25°C (77°F) the rate of development is increased such that hatching takes place in 5 days followed by metamorphosis in 2 1/2 months. Larval development of the leopard frog was found to be accelerated by an increase in temperature up to the CTM by Atlas (1935). Volpe (1953) found that the rate of the embryonic development of toads (Bufo sp.) was increased up to a limiting temperature of 35°C (95°F).

No specific study was conducted to determine if the development of anuran eggs and larvae was more rapid south of Transect F than north of Transect F, but some evidence of this was indicated for at least one species. With approximately equal sampling effort, the ratio of adult to larval southern cricket frogs collected or observed through the 1975 breeding season was much higher south of Transect F (86/11) than north of Transect F (25/88). Assuming breeding took place at the same time, which may not be true since calls continued a month later at the upper impoundment, those ratios indicated accelerated development with metamorphosis occurring earlier at the lower impoundment.

The combined thermal impact on the reproduction, development, and growth of the amphibian species exposed to the increased heat was not considered a significant threat to the continued existence of those species or population balances within the study area. Given that Unit 2 had been in operation for approximately four years prior to the current study, the presence of the amphibian species was considered evidence of successful reproduction, development, and growth throughout the study area during that period of time.

8.3 Reptiles

8.3.1 Methods

Data pertaining to the reptiles of Robinson Impoundment and Black Creek were gathered by observation and collection of specimens throughout all phases of the biological sampling programs conducted within the study area.

Most of the observations and collections were made in conjunction with the other terrestrial zoology studies, with supplemental information provided by observations and collections made during aquatic and fishery sampling.

In most instances, captured specimens were identified in the field and released unharmed. Collected specimens were preserved in 10% formalin, returned to the laboratory for positive identification, cataloged, and retained in a reference collection. Essential details of all observations and collections were coded on computer data cards to facilitate interpretation and analysis.

8.3.2 Results and Discussion

Species Observed

Twenty reptilian species were identified during the field studies conducted at Robinson Impoundment and Black Creek (Table 8.3.1). Of those, seven species of turtles and three species of snakes were considered to be dependent upon the aquatic ecosystems of the impoundment or Black Creek for some portion of their life cycle. The remaining ten species were considered to be terrestrial and not likely to be exposed to any effects of the thermal discharge. The following results and discussion centers on the ten aquatic or semi-aquatic species found to be present within the study area.

Observed Distributions

The observed distribution of each species is summarized in Table 8.3.2 by the number of observations or collections of each species from five generalized regions of the study area. Those regions were Black Creek north of the impoundment, Black Creek south of the impoundment, the impoundment north of Transect F, the impoundment south of Transect F, and the discharge canal (Figure 8.2.1).

Little can be said concerning the actual distribution of several of the observed species within the study area. During the course of the study, only single specimens of river cooter (Chrysemys c. concinna) and red-bellied turtle (Chrysemys rubriventris) were observed. Both of these observations occurred in the impoundment south of Transect F. Four observations of snapping turtles (Chelydra serpentina) were recorded at the same location on Black Creek several hundred meters below the impoundment. Because snapping turtles rarely bask (Conant, 1975), other specimens may have gone undetected during the study.

A greater number of observations made possible a better understanding of the distributions of spotted turtles (Clemmys guttata) and chicken turtles (Deirochelys r. reticularia). Spotted turtles were found to occur along the shoreline of the impoundment north of Transect F, as well as in the swamps adjacent to Black Creek south of the impoundment. Chicken turtles were sighted on several occasions at the impoundment north of Transect F but only once at the impoundment south of Transect F.

A relatively large number of observations of stinkpots (Sternotherus odoratus) and yellow-bellied turtles (Chrysemys s. scripta) enabled a better determination of their respective distributions. Stinkpots were seen throughout the impoundment and in Black Creek north of the impoundment with most of the observations reported from the impoundment south of Transect F. Yellow-bellied turtles were found in both regions of the impoundment as well as at Black Creek south of the impoundment. The majority of those observations were made in the impoundment north of Transect F. Many of the unidentified turtles observed and reported in Table 8.3.2 were believed to have been yellow-bellied turtles. Special note should be made of the fact that during the course of the study twelve yellow-bellied turtles and one stinkpot were observed in a shallow outpocket of the discharge canal.

Specimens of all three species of aquatic snakes known to occur in the study area were observed throughout the impoundment and at Black Creek north and south of the impoundment. Both the banded water snake (Natrix f. fasiata) and the brown water snake (Natrix taxispilota) were encountered most frequently along the shoreline of the impoundment south of Transect F. The majority of eastern cottonmouth (Agkistrodon p. piscivorus) observations were made in the swampy areas adjacent to Black Creek north and south of the impoundment and in the marshy areas along the shores of the impoundment north of Transect F.

Dependence on the Aquatic Ecosystem

The life histories of each of the ten aquatic or semi-aquatic reptilian species identified within the study area are closely associated with the waters of Robinson Impoundment and Black Creek. For those species to be present and continue to exist in the study area, the impoundment and Black Creek must meet the specific habitat and physiological requirements of each. Although the nature and extent of dependence on the aquatic ecosystem varies for each species, the impoundment and Black Creek must provide such thermally dependent conditions as appropriate escape cover, adequate food supply, and a suitable medium in which thermoregulation can be achieved.

Escape cover for any species must provide an appropriate refuge or escape route for disturbed or threatened individuals. Although the open water of the impoundment and Black Creek performed this function to some degree, the aquatic vegetation was of more importance. Essentially all observations of the chelonian and serpentine species found within the study area were made in or near significant beds of vegetation (Figures 7.2.1 to 7.2.4).

Beds of vegetation not only provide escape cover, but also, serve as a source of food for the aquatic and semi-aquatic reptiles. Some species feed directly on the vegetation while other species feed on the fauna associated with the vegetation. Carr (1952) reported the food habits of snapping turtles, yellow-bellied turtles, red-bellied turtles, and chicken turtles to be essentially omnivorous. A study of yellow-bellied turtles of South Carolina by Clark and Gibbons (1969) found evidence which showed that juveniles tended to be primarily carnivorous with adults becoming generally herbivorous. Carnivorous food habits were reported for the spotted turtle and stinkpot (Carr, 1952), as well as, for the eastern cottonmouth and the banded and brown water snakes (Wright and Wright, 1957). No food habit studies were performed on the reptiles collected from Robinson Impoundment and Black Creek.

The existence and survival of the reptiles directly depends on the ability to successfully thermoregulate within the surrounding environment. If temperatures of the environment rise above or fall below the range where normal activities and functions can be performed, each animal must be able to behaviorally or physiologically thermoregulate in order to survive (Brattstrom, 1965).

Thermal Effects on Distribution

Experiments which established values for critical thermal maximum (CTM) and maximum voluntary temperatures (MVT) for many reptilian species have been reported in the literature. The values available for species found within the study area are presented in Table 8.3.3. Caution must be exercised in interpreting and drawing conclusions from the information in Table 8.3.3 because the values for the CTM and MVT were experimentally determined for specimens which, in many cases, were collected from regions with colder climates than the Robinson study area. Those specimens very likely exhibited considerably lower CTM and MVT values than expected for specimens acclimated to a more southern locality.

Based on the CTM and MVT values in Table 8.3.3, the water temperature data presented in CP&L Exhibit 2.1, and the conclusions expressed in Sections 6.0 and 7.0, the distributions of some of the aquatic and semi-aquatic reptilian species within the study area were limited both directly and indirectly by the thermal discharge. The direct effect of the increased heat on the distribution of reptiles resulted from the existence of exclusion areas centered at the mouth of the discharge canal during the summer months. The actual size and duration of the exclusion areas varied for each species based on specific thermal tolerances. The reptilian collections and observations reported in Table 8.3.2 generally supported the occurrence of the exclusion areas.

Regardless of the size and duration of the exclusion areas, the actual impact was probably reduced by several considerations. Due to habitat preference, not all of the reptilian species identified at Robinson Impoundment were likely to occur in the thermally affected areas. Species including the spotted turtle, river cooter, and eastern cottonmouth were among that group. The red-bellied turtle which was observed a single time at Robinson Impoundment was considerably removed from the reported range of that species, and may have been artificially introduced by escape or release from captivity. Although the CTM of several of the remaining six species was exceeded near the point of thermal discharge, no deaths were likely to have resulted since the individuals of those species were expected to have moved away from the exclusion areas as the water temperature reached and exceeded the respective MVT requirements.

Another consideration was that cooler refuge areas existed within or adjacent to the reported exclusion areas. Those refuge areas included springs and streams and the associated swamps or marshy areas at the edge of the impoundment and along Black Creek. Each of these refuge areas provided a suitable habitat where the displaced reptiles were able to survive during the periods when the exclusion areas existed. A negative impact of movements into the refuge areas may have resulted due to increased competition for available food supplies.

Because the aquatic vegetation of the impoundment provided both cover and food, any thermal effects on the distribution and productivity of that vegetation and the associated fauna were assumed to cause corresponding indirect effects on the distributions of the aquatic and semi-aquatic reptiles. Because the distribution and productivity of aquatic vegetation and benthos were reduced near the point of thermal discharge by the increased temperatures during the summer months (Section 6.0 and 7.0), the dependent reptilian species were probably forced to move to adequate food and cover if not previously forced to move due to direct effects of the increased temperatures. It was not possible to separate the impact of direct and indirect thermal effects on the observed distributions of reptiles.

Thermal Effects on Growth and Reproduction

Other effects that may result from the increased heat load on Robinson Impoundment relate to the growth and reproduction of the reptilian species. Although no special studies were conducted at the study area to determine the nature or extent of this possible impact, some previous work was reported by Gibbons (1970) on the yellow-bellied turtles (*Chrysemys scripta*) of Par Pond, a thermally influenced reservoir at the ERDA Savannah River Plant, Aiken, South Carolina.

Gibbons' studies indicated that specimens from an experimental population at Par Pond exhibited exceptionally large individual body sizes and extraordinary juvenile growth rates when compared to specimens from a control population. Increased water temperature was ruled out as being a direct cause of those observations, but was offered as a possible indirect cause by increasing the productivity at lower trophic levels. As a result of the increased productivity, a diet of higher protein content was made available to and utilized by the turtles. Further observations by Gibbons indicated an increased reproductive potential for the Par Pond population. That conclusion was based on findings that the females of the experimental population tended to lay more eggs per clutch and possibly more clutches per year than the control populations.

8.4 Avifauna

8.4.1 Methods

Quarterly quantitative sampling began in August, 1974 and ended in February, 1976. Quantitative observations were recorded at the stations shown in Figure 8.4.1. During each quarter, one morning and one evening survey were conducted along the east and west shorelines. Qualitative observations were recorded during monthly visits to the impoundment.

8.4.2 Results and Discussion

To facilitate data analyses and discussion, the aquatic avifauna (44 species) were grouped into categories based upon taxonomic and ecological similarities. Each category will be discussed individually. Similarly, the impoundment was divided into three sections (Figure 8.4.1) based on relative heat load. Sections I and II received heat from the discharge, Section III did not. Black Creek observations are discussed separately.

During the sampling, a large number of nonaquatic avifauna (91 species) were identified around the impoundment and along Black Creek. These observations will not be discussed, but are included in Table 8.4.4 to provide additional information on the species diversity and seasonal changes of the bird populations in the Robinson Impoundment area.

A species list of the avifauna (135 species) observed at Robinson Impoundment and Black Creek during the study is presented in Table 8.4.3.

Grebes, Three Species (Table 8.4.1)

Grebes are small, recreationally unimportant waterbirds found throughout the United States on inland lakes and along coasts. Grebes are weak flyers but strong swimmers, and are entirely dependent on the aquatic ecosystem for food. Martin et al. (1951) states that grebes are entirely carnivorus feeding primarily on fish, crustaceans, aquatic insects, and mollusks.

At the Robinson Impoundment, grebes were present primarily during fall and winter. Of the total number of waterfowl observations made (3,704), grebes accounted for only 2% (92) of the total (Table 8.4.2). Grebes were not restricted to any specific area of the impoundment and were noted in approximately equal numbers in heated and unheated portions of the impoundment (Table 8.4.2). Brisbin (1973) also reported no significant differences in distribution of grebes between heated and unheated portions of his study area on the ERDA Savannah River Plant.

Grebes are entirely dependent upon the aquatic ecosystem for food and apparently show no aversion to heated water. The availability of suitable habitat for their major food species was the overriding factor which determined their distribution in Robinson Impoundment. During the months when grebes were most common on the impoundment, the water temperatures were well within the tolerances limits for their major food items and did not restrict their distribution. During the study no adverse effects upon the grebes from the heated effluent were noted.

Surface-Feeding Ducks, Seven Species (Table 8.4.1)

The surface-feeding or dabbling ducks were the most important group of water birds (from a recreational standpoint) at Robinson Impoundment.

All seven species were highly prized and actively sought during the South Carolina waterfowl hunting season. In addition, the wood duck (Aix sponsa), which is the only species known to nest in the Robinson Impoundment area, was included in this group. As a group, surface-feeding ducks utilized the aquatic ecosystem in two ways--as a resting site, and as a feeding area.

Surface-feeding ducks are almost entirely vegetarian with the bulk of their diet composed of aquatic species such as wild millet (Echinochloa spp.), smartweed (Polygonum sp.), bulrush (Scirpus spp.), pondweed (Potamogeton spp.), wigeongrass (Ruppia maritima), and a variety of other species (Martin et al. 1951). An exception to this is the wood duck whose primary foods are acorns, hickory nuts, and the aquatic vegetation associated with the wooded swamps where it spends much of its time (Martin et al. 1951). Smart weed, bulrush, and pondweed were observed at the impoundment (Section 7.0). The small amount of animal matter consumed by this group consists primarily of the immature aquatic insects.

At Robinson Impoundment, members of this group were observed during all seasons of the year. Their numbers peaked during fall migrations and during the return flight in the spring.

The 516 observations recorded for this group during the study comprised 14% of the total (Table 8.4.2). Wood ducks were the most commonly observed species.

Brisbin (1973) identified this group as the most thermally intolerant of those he studied. He further stated that no individuals from this group were ever observed in the heated portion of his study area, and a superficial examination of the distribution data recorded for this group at the impoundment supports his conclusions. There are, however, three factors other than heat present at Robinson Impoundment which could have had a significant impact on the distribution of this group in the impoundment.

First, preferred habitat for surface-feeding ducks was not equally distributed between the heated and unheated portions of the impoundment. Eighty-eight percent of the observations for this group were recorded from the upper impoundment which is not subjected to thermal stress, but which does contain the major areas of preferred habitat for this group. Several small areas of shallow marsh do exist in the heated portion of the impoundment and on several occasions surface-feeding ducks were observed in these areas. Of the twelve percent of the observations for this group recorded below the bridge, eleven percent were in the area subjected to the greatest thermal stress.

Second, the shallow marsh areas below the bridge which form the preferred habitat for surface-feeders are either situated near residential areas along the impoundment or are visited frequently by boaters and fishermen. Utilization of these areas by surface-feeding ducks was reduced as a result of frequent disturbance.

The third factor contributing to the distribution of this group in Robinson Impoundment is the temperature difference between the heated and unheated areas of the impoundment. Brisbin (1973) reports temperatures of 30-35°C in his heated study area at the Savannah River plant during the winter months when this group is most abundant. Robinson Impoundment temperatures in the heated area averaged approximately 10-15° cooler during the winter months. It appears likely that the surface-feeding ducks may be adversely affected by temperatures above the 30°C mark, but when cooler temperatures prevail, the presence and suitability of preferred habitat has the strongest influence on distribution.

In general, the seasonal abundance of this group at Robinson Impoundment and the preference for habitat areas away from the heated effluent make it unlikely that there is a significant impact attributable solely to heat.

Diving Ducks, Nine Species (Table 8.4.1)

In terms of recreational importance, the diving ducks rank second behind the surface-feeding ducks. Most hunters consider them to be inferior in quality as table fare, and while they may be taken occasionally, are usually not actively hunted as a group. Diving ducks are generally thought to be primarily animal feeders giving rise to the commonly used term "fish duck." Martin et al. (1951), however, cites numerous studies which show that, except for the mergansers and the bufflehead, plant matter constitutes the major portion of their diet. Plant species known to comprise a significant food source for this group include pondweed (*Potamogeton sp.*), muskgrass (*Chara sp.*), coontail (*Ceratophyllum demersum*), watershield (*Brasenia schreberi*), and wigeongrass (*Ruppia maritima*). Most of the animal food consists of immature aquatic forms of insects, crustaceans, fish, and mollusks. Mergansers and buffleheads are primarily fish eaters, with the remainder of the diet consisting of crayfish, shrimp, frogs, and insects (Martin et al. 1951).

Diving ducks usually frequent the open water areas of lakes where they may flock together in large "rafts" to rest and feed. As a group, diving ducks tend to migrate later than other waterfowl, usually moving south just ahead of temperatures which freeze their resting and feeding grounds. At Robinson Impoundment, observations of this group confirmed these behavioral characteristics.

The greatest concentrations for this group were noted in November and February quarterly samples, when rafts of up to 150 birds of a given species were often recorded. Of the 544 observations recorded for this group, 71% were from the lower third of the impoundment, and 21% from the middle third near the heated discharge. In summary, 92% of the observations for this group came from the areas of the impoundment subject to thermal influence. Brisbin (1973) reported similar results regarding seasonal abundance and species observed, from this group, and stated that while there was a significant difference in abundance between heated and unheated portions of his study area, the diving ducks appeared less thermally sensitive than the surface-feeding ducks.

Robinson Impoundment provides suitable habitat for several species of diving ducks, and during the time when they are present they do not seem to be adversely affected by the heated effluent.

Herons, Egrets, Bitterns, Eight Species (Table 8.4.1)

Members of this group of waterbirds are restricted to the water margin habitat along lakes and rivers. They are commonly observed in marshy or swampy areas wading slowly in the shallows in search of food. Birds of this family have little economic or recreational importance. They are, however, directly dependent on the aquatic ecosystem as a food source. These birds are primarily carnivorus, with fish, crustaceans, amphibians, mollusks, and insects forming the major portion of their diet (Martin et al. 1951).

Members of this group were observed year-round at the impoundment with slightly greater numbers and diversity during spring and summer months. Thirty observations of this group accounted for one percent of the total. Distribution in the impoundment area was as expected considering the habitat requirements for this group. Half (50%) were noted in the marshy areas above the bridge with the remainder observed in the scattered suitable areas in the heated portion of the reservoir.

Since these birds are not truly aquatic, the heated water does not affect them directly. They do, however, rely on the marshy areas around the impoundment for food, and changes in the distribution of these areas or their suitablility as habitat for the aquatic species which form the prey for this group would adversely affect these birds. Data presented in Section 7.0 (Aquatic Vegetation) indicate that heat has reduced the potential for growth of aquatic plants in some areas of the impoundment. However, the small number of birds of this group observed and the limited areas of vegetation affected by the heat do not constitute a significant impact on the population present.

Rails, Two Species (Table 8.4.1)

Of the two species of this group at Robinson Impoundment, the coot was the most noteworthy. Coot are one of the most abundant waterbirds in the U. S. and may be exceeded in numbers only by the mallard and pintail (Martin et al. 1951). Coot are often erroneously referred to as "ducks," but are in fact more closely related to rails or "marsh hens." They are not recreationally important and are often considered a nuisance in areas where they congregate.

Coot feed almost entirely on aquatic vegetation with duckweed (*Lemna* sp.), wigeongrass (*Ruppia maritima*), various algae and muskgrass (*Chara* sp.) being of primary importance (Martin et al. 1951). The small amount of animal food consists mainly of aquatic insects.

At Robinson Impoundment, coot were the most frequently observed species, comprising 60% of the aquatic birds observed. Such high numbers of coot are not uncommon based on evidence from other southeastern study areas. Coot accounted for 66% of the total number of waterfowl observed by Brisbin (1973), and he cites other studies (Pratt, 1969; Dopson, 1964) where similar results were obtained.

Highest numbers were observed during November and February quarterly samples, again similar to results observed elsewhere in South Carolina. Within the reservoir, 94% of the coot observations were recorded from the heated portions of the reservoir (Table 8.4.2). Large flocks of coot were observed in coves and in the open water from the discharge point to the dam. Based on these observations, the heated effluent obviously had no adverse effect upon coot.

The other member of this family, the king rail, inhabits the tall marsh grasses where it feeds primarily on insects. At the impoundment, king rails were most common in late summer and autumn in the marshy areas above the SR 346 bridge.

Shorebirds, Five Species (Table 8.4.1)

Like the herons, members of this group are lake margin inhabitants often seen near the water's edge along sandy shoreline areas. Shorebirds feed almost exclusively on animal matter, with insects, especially immature aquatic forms, small crustaceans, mollusks, and worms the most important groups (Martin et al. 1951).

At Robinson Impoundment, members of this group were observed year-round but were most abundant during spring and summer. Two percent of the total observations recorded were of this group (Table 8.4.2). Their preference for relatively barren beach areas was reflected by their distribution at the impoundment. Observations for this group were recorded from the lower sections of the impoundment where such habitat exists.

If the thermal effluent restricts the distribution of food items for this group within the impoundment, corresponding shifts in the distribution of shorebirds would occur. Benthic data (Section 6.0) indicate that the heated discharge has little or no impact upon aquatic invertebrates in the lower sections of the impoundment where shorebirds were most common. Therefore, there was probably no adverse impact upon this group attributable either directly or indirectly to heat.

Gulls and Terns, Five Species (Table 8.4.1)

The gulls and terns observed at the impoundment are common visitors to inland waters. This group spends much of its time on land, but feeds almost exclusively on the water. Terns feed primarily upon fish but also take insects and other aquatic fauna. Gulls are scavengers, subsisting to a large degree on fish, crustacea, insects, and aquatic garbage.

This group has been observed during all seasons at Robinson Impoundment, but are most common during winter and spring. Observations of this family accounted for five percent of the total. Ninety-four percent (94%) of the observations for this group came from the heated portion of the impoundment, indicating possible attraction to, or at least no adverse affects from, the heated effluent.

<u>Miscellaneous, Five Species</u> (Table 8.4.1)

The five species discussed here do not conveniently fit into the larger groups discussed previously and, except for the kingfisher, were recorded infrequently or in such small numbers that separate discussion is unnecessary. They do depend upon the aquatic ecosystem when present, however, and thus merit at least brief mention.

Kingfishers which feed primarily on fish (Martin et al. 1951) were year-round residents of Robinson Impoundment. Since they were restricted to specific habitats around the lake and were not present in large numbers, impact from thermal effluent was considered minimal.

The Canada goose and whistling swan occasionally rested on the impoundment for short periods during migrations. Their habitat preferences and food requirements were similar to the surface-feeding ducks and if present in larger numbers would be subjected to the same type of thermal impact.

The common loon and the double-crested cormorant were also infrequent visitors to Robinson Impoundment. Feeding primarily upon fish, both species closely resemble the diving ducks in their relationship with the aquatic ecosystem and the potential for impact from the heated effluent.

<u>Black Creek Below the Impoundment</u>

Below Robinson Impoundment, Black Creek flows through a cutover gum-cypress swamp until it reaches Prestwood Lake in the city of Hartsville. Swamps of this type are poor habitat for the majority of waterfowl observed in the Robinson area, but are occasionally used by surface-feeding ducks as resting and feeding areas. Three locations (Transects H, K, L) (Figure 8.4.1) were used as sampling stations. Observations were recorded for two ten-minute periods during each quarterly sample. Table 8.4.5 summarizes the Black Creek observations. Wood ducks were the most commonly observed waterbird along Black Creek, and were observed nesting in suitable locations along the stream.

The only other aquatically dependent birds observed along Black Creek were the spotted sandpiper, American bittern, and belted kingfisher. Both the sandpiper and the bittern were observed on only one occasion at transect H just below the impoundment outfall. Kingfishers were observed at all locations along the creek.

The wood duck was the only waterfowl species which frequented the swamp along the creek on a regular basis. Even though wood ducks nest in the Black Creek swamp, it is unlikely that the temperatures recorded in the creek affected breeding success or brook survival. Based on our observations, the heated effluent has no effect on aquatic avifauna in the Black Creek swamp.

8.5 Mammals

8.5.1 Methods

Three methods were used to gather information on mammal populations and distributions at Robinson Impoundment and along Black Creek. First, live trapping was conducted during quarterly samples at ten stations around the impoundment and at two stations along Black Creek (Figure 8.5.1). Traps were set along the impoundment shore using fish as bait. Second, suitable shoreline areas around the impoundment were examined for tracks, scats, and other signs of mammal activity. Third, observations were recorded during all phases of biological sampling and during early evening trips along shoreline areas.

8.5.2 Results and Discussion

Fifteen species of mammals were identified as resident in Robinson Impoundment area (Table 8.5.1). Of these species, five (beaver, muskrat, raccoon, mink, and otter) were determined to depend on or interact with the aquatic ecosystem to the extent that changes in the aquatic ecosystem could affect their habits.

The remaining species may interact with the aquatic ecosystem on an occasional basis but were probably not influenced to any great degree by changes within the impoundment.

Since each species interfaced with the aquatic ecosystem in a manner different in both type and degree from the others, a separate discussion of each is presented.

Beaver (Castor canadensis)

Beaver were once extinct in South Carolina but restocking efforts on the Sandhills National Wildlife Refuge reintroduced this species to the Robinson area. During the study, observations indicated that beaver were the most numerous aquatic mammal in Robinson Impoundment. Figure 8.5.3 shows the location of actual sightings and indications (scats, girdled trees, scent mounds) of beaver activity along the shoreline. Thirteen lodges (Figure 8.5.2) in various states of repair were located along the impoundment shore and in Black Creek.

Beavers interact with the aquatic ecosystem in a number of ways. The lodges and felled trees along the shoreline provide shelter for fish and sunning areas for turtles and snakes. In some areas beavers impound tributary streams creating additional habitat for all aquatic species. A large part of the diet of beavers is aquatic in origin. Jackson (1961) states that in summer beavers feed primarily on sedges, rushes, water grasses, lily pads, roots and tubers of water plants, and twigs of shoreline woody vegetation. Such vegetation is present in several areas along the impoundment shoreline.

Beavers, as is the case with all mammals, thermoregulate to avoid the effects of extreme heat or cold, thus the direct effect of the heated effluent on beavers was minimal. However, since beaver depend primarily on aquatic plants for food, especially during the summer months, any changes in the extent of present beds of vascular vegetation could result in a concomitant shift in numbers and/or distribution of the beavers in the impoundment. Data reported in Section 7.0 (Aquatic Vegetation) indicated that no significant changes in the distribution of aquatic vegetation were apparent. It is, therefore, probable that beavers are unaffected by the thermal discharge.

Muskrat (*Ondatra zibethica*)

Like the beaver, the muskrat spends much of its life and derives much of its food from the aquatic ecosystem. Muskrats are usually found in swampy or weedy portions of lakes and streams where they feed chiefly on aquatic plants, the most important of which are cattails (*Typha* sp.), arrowhead (*Sagittaria* sp.), spike rush (*Eleocharis* sp.), bullrushes (*Scirpus* sp.), pickerel weed (*Pontederia* sp.), and pond weed (*Potamogeton* sp.) (Jackson, 1961). Although primarily herbivorus, muskrats have been reported to feed upon clams, fish, snails, and crayfish (Golley, 1966, Jackson, 1961). Muskrats are known to fall prey to a number of species including mink, fox, large turtles, aquatic snakes, and larger predatory fish.

Robinson Impoundment and Black Creek support a small population of muskrats. Signs were observed in several localities in the study area (Figure 8.5.4) and were usually found in areas where aquatic vascular vegetation is present. It is possible, however, that competition with beavers for available food may be a factor limiting potential expansion of the muskrat population. In addition, Blair, et al. (1968) and Hall and Kelson (1959) list the South Carolina coastal plain as the southeastern edge of the muskrat's range in North America.

Since thermal load in the impoundment has essentially the same effect on muskrats as on beavers, and because of the smaller number of animals involved, the potential for damage to the muskrat population is proportionally greater. Since the major beds of vascular vegetation are unaffected by heat, interspecific competition with beavers and the fact that the impoundment is on the edge of the muskrat's range are two factors limiting the muskrat population in the impoundment.

Mink (*Mustela vison*)

The mink, while not truly aquatic, is seldom encountered far from water. This active carnivore inhabits pond, lake, and stream edges particularly in brushy or forested areas. Although mink spend little time actually in the water, aquatic or amphibious vertebrates and invertebrates form a major portion of their diet. Jackson (1961) reports that crayfish formed a significant percentage (68%) of the summer diet of mink, with frogs and fish also prevalent. Golley (1966) reports that mink in South Carolina are known to feed on fish, frogs, snakes, birds, aquatic insects, and muskrats.

One specimen was captured in a live trap set along the shoreline of the impoundment approximately 3/4 mile north of the plant. Other sign of mink activity in the study area is indicated in Figure 8.5.4.

Mink were probably at or near the top of the food web at Robinson Impoundment and as such were not subject to direct effects of thermal load in the impoundment. Since mink are not dependent upon any single group of aquatic aniamls, but feed upon a variety of aquatic and terrestrial organisms no impact from the heated effluent was identified.

Raccoon (*Procyon lotor*)

Like the mink, the raccoon is a terrestrial mammal which spends much of its time and obtains much of its food from aquatic habitats. Raccoons are usually classed as omnivores with the ratio of plant to animal matter in their diet subject to considerable variation. Jackson (1961) reports that as much as 70% of a raccoons diet may consist of animal matter with the chief foods being crayfish, snails, clams, insects, frogs and tadpoles, shallow water fish, immature turtles, and other animal matter. The remainder of their diet consists primarily of nuts, seeds, and fruit of a variety of plants (Golley, 1966; Jackson, 1961; Burt and Grossenheider, 1964).

Raccoon signs were observed along most of the suitable shoreline areas around the impoundment and in the swamps along Black Creek. (Figure 8.5.5). Several road kills were noted on roads near the impoundment.

The variety of habitats utilized by raccoons and the varied diet which does not depend on one specific group of organisms preclude significant impact from the heated effluent.

Otter (*Lutra canadensis*)

Of all the mammals observed in Robinson Impoundment area, the river otter was the most dependent upon the aquatic ecosystem.

Otters spend most of their time in the water, feed almost entirely upon aquatic prey, and may travel up to 15 miles along a stream or lake in search of food (Burt and Grossenheider, 1964). Exclusively carnivorus, the otter is at or near the top of the aquatic food web. Numerous studies indicate a preference for crayfish during summer months when they are easily caught, but fish probably constitute the major portion of the otter's diet. Jackson (1961) sites a study in which forage fish comprised 40% of the diet of otters followed by amphibians (25%), game and pan fishes (23%), crayfish 7%), and miscellaneous vertebrates (5%). Golley (1966) states that otters in South Carolina eat fish, crustacea, insects, birds, muskrats, and clams, with the major fish consumed being carp, suckers, and sunfish.

Otters were observed on several occasions feeding in the upper end of the impoundment and signs were noted both in the heated portion of the impoundment and in Black Creek below the dam. (Figure 8.5.5). Examination of otter feces in the impoundment revealed the presence of fish scales identified as belonging to suckers of the genera *Erimyzon* and *Minytrema*.

In view of the close relationship to the aquatic ecosystem displayed by the otter, heated effluent in the impoundment could have an effect on the otter population by limiting the fishery resources available to it for prey. However, data presented in Section 4.0 (Fisheries) indicate that no reduction in fish populations of a magnitude great enough to affect the otter population in the impoundment has occurred. The otter observations at the impoundment were for the most part confined to the upper impoundment away from the heated effluent. This combined with the variety of fish available as prey and the large home range of otters eliminates the possibility of impact upon otters by the heated effluent.

8.6 Summary and Conclusions

Amphibians

Twenty-two species of amphibians were identified within the study area. Needs common to all individuals of those species at Robinson Impoundment or Black Creek included water temperatures within tolerable ranges, cover, food, and breeding sites. Each of those needs was considered subject to possible thermal influence.

Comparison of observed water temperature data with available temperature tolerance values indicated that thermal exclusion areas existed within the impoundment during the summer months. However, the expected and observed habitat preferences and requirements were considered primarily responsible for the restriction of most of the amphibian species to shallow, more heavily vegetated margins of the impoundment. As a result, the exclusion areas were believed to have had little effect on the overall distribution of the amphibians within the study area.

The thermal limitation of the distribution and productivity of aquatic plants and benthic fauna probably indirectly influenced the distributions of at least two of the amphibian species by reducing the available cover and food supply. But again, habitat preferences and requirements were believed to exclude most species from any serious distributional impact resulting in that way.

Thermal limitation of the distribution of aquatic vegetation probably had some indirect effect on reproduction and larval development of some anuran species in the area of the impoundment adjacent to the point of thermal-discharge by limiting the availability of suitable habitat. Breeding seasons of four anuran species were found to differ slightly between heated and unheated portions of the impoundment. At least for one species, there was evidence which indicated the possibility of accelerated development as a result of increased heat. Although water temperatures throughout much of the study area exceeded the reported literature values for embryonic and larval tolerances, the water temperatures recorded in appropriate breeding habitat indicated the availability of cool enough water for successful reproduction and larval development throughout the impoundment and Black Creek. The combined thermal impact on the reproduction, development, and growth of the amphibian species exposed to the increased heat was not considered a significant threat to the continued existence of those species or population balances within the study area.

Reptiles

Ten species of aquatically dependent reptiles were found to occur within the study area. Another ten species were identified but were considered terrestrial and not subject to any thermal stress resulting from the operation of Unit 2. The aquatic and semi-aquatic species depended on the ecosystems of Robinson Impoundment and Black Creek for such thermally influenced factors as water temperature within the tolerable ranges, appropriate cover, and adequate food supply.

A direct effect of increased heat on the distribution of reptiles resulted from the existence of seasonal thermal exclusion areas. The size and duration of those exclusion areas varied by species based on respective thermal tolerances. Regardless of the size and duration, the actual impact of each exclusion area was believed to be minimized by several considerations. Specific habitat preferences or requirements other than temperature tolerances restricted some of the species from inhabiting the thermally affected areas of the impoundment. For those species which did occur in the thermally affected area, cooler refuge areas existed within or adjacent to the exclusion areas and provided a suitable habitat where displaced reptiles could survive critical periods.

The thermal effects on the distribution and productivity of the aquatic vegetation and benthos during the summer months probably caused some corresponding indirect effects on the reptilian distributions near the point of thermal discharge. It was not possible to separate the impact of that indirect effect from the direct effect of heat on the observed distributions of reptiles.

Increased body size and juvenile growth rate were reported in the literature as a possible indirect effect of increased water temperatures on one species of turtle. Whether that was true at Robinson Impoundment for that species or any other species was not determined.

Avifauna

Robinson Impoundment provides an attractive habitat for a wide variety of aquatic avifauna. Three thousand seven hundred four observations from seven groups of aquatic birds (44 species) were recorded (Table 8.4.2). Coot accounted for 60% of the total observations, and the recreationally important surface-feeding and diving ducks totaled 14% and 15%, respectively. Comparisons of the species composition and relative abundance of avifauna present at Robinson Impoundment with those recorded at the Sandhills National Wildlife Refuge, the ERDA Savannah River Plant, and other study areas in the Southeast, indicate little or no difference. It is apparent that Robinson Impoundment does not differ from other such bodies of water in the numbers and types of aquatic avifauna which are attracted to it, and that a balanced indigineous population of avifauna is being maintained.

Within the impoundment, the availability of suitable habitat determined the distribution of the species. Habitat for a given group did not differ in its attractiveness between heated and unheated portions of the impoundment in any way that could be attributed to heat load.

Within habitat types, the effects of the thermal effluent on aquatic avifauna are indirect. Each group of waterbirds utilizes one or more components of the aquatic ecosystem as a food source. Impact upon these components by the heated effluent would result in changes in numbers and distribution in the higher trophic levels occupied by aquatic birds. Data presented in Sections 4.0, 6.0, and 7.0 indicate that these lower trophic levels were not impacted to the extent that the avifauna utilizing them as a food source were affected.

Mammals

Fifteen species of mammals were observed at Robinson Impoundment and Black Creek during the study period. Five species were determined to interact with the aquatic ecosystem to a significant extent.

The presence of the impoundment created a series of habitats which encouraged establishment of populations of such species as beaver and muskrat which would not be present in such numbers in a nonimpoundment situation. The mammalian populations we have examined appear to be in a favorable balance on both an intra- and interspecific level.

The ability of mammals to thermoregulate precludes any direct effect of the heated effluent upon species residing in the water. Availability of suitable habitat was the factor determined to have exercised the greatest influence on mammal distributions at Robinson Impoundment and along Black Creek. Where suitable habitat was available for a given species in both heated and unheated sections of the impoundment, no difference in the distribution of mammals associated with the habitats could be discerned.

Conclusion

Given that the combined thermal effluent from Units 1 and 2 operation has been discharged into Robinson Impoundment since September, 1970, the terrestrial vertebrate species and populations observed during the current study were considered to have adapted to any thermal stress imposed during that period. After five years, those species and populations have approached an equilibrium with the existing conditions at the impoundment including any changes which resulted from the increased heat load. The thermal impact on the terrestrial vertebrates was not considered great enough to threaten the existence or maintenance of the balanced indigineous populations found to occur at the impoundment and Black Creek during the study.

8.7 Literature Cited

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Table 8.2.1 Amphibian species collected and/or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976. (Nomenclature follows Conant, 1975)

Scientific Name	Common Name	Impoundment	Black Creek
Siren intermedia intermedia	Eastern lesser siren	X	X
Necturus punctatus	Dwarf waterdog	X	X
Amphiuma means	Two-toed amphiuma		X
Desmognathus fuscus	Dusky salamander	X	
Stereochilus marginatus	Many-lined salamander		X
Pseudotriton montanus	Mud salamander	X	X
Pseudotriton ruber	Red salamander	X	
Eurycea bislineata	Southern two-lined salamander	X	X
Eurycea quadridigitata	Dwarf salamander		X
Bufo americanus	American toad	X	
Bufo terrestris	Southern toad	X	X
Bufo woodhousei fowleri	Fowler's toad	X	
Acris gryllus gryllus	Southern cricket frog	X	X
Acris crepitans crepitans	Northern cricket frog	X	
Hyla crucifer	Spring peeper	X	X
Hyla cinerea	Green treefrog	X	X
Hyla squirrella	Squirrel treefrog	X	
Limnaoedus ocularis	Little grass frog	X	
Rana catesbeiana	Bullfrog	X	X
Rana virgatipes	Carpenter frog	X	X
Rana clamitans	Bronze frog	X	X
Rana utricularia	Southern leopard frog	X	X

August 1974 through May 1976

Species	Black Creek South of Impoundment			Impoundment[1] North of Transect F			Impoundment[1] South of Transect F			Discharge Canal		
	Larvae	Adults	Calls	Larvae	Adults	Calls	Larvae	Adults	Calls	Larvae	Adults	Calls
<u>Siren intermedia intermedia</u>	0	1	-	7	4	-	0	9	-	0	0	-
<u>Necturus punctatus</u>	0	1	-	9	7	-	0	1	-	0	0	-
<u>Amphiuma means</u>	0	2	-	0	0	-	0	0	-	0	0	-
<u>Desmognathus fuscus</u>	0	0	-	0	0	-	0	1	-	0	0	-
<u>Stereochilus marginatus</u>	2	0	-	0	0	-	0	0	-	0	0	-
<u>Pseudotriton montanus</u>	0	1	-	2	0	-	5	0	-	0	0	-
<u>Pseudotriton ruber</u>	0	0	-	0	0	-	10	0	-	0	0	-
<u>Eurycea bislineata</u>	21	0	-	28	1	-	252	3	-	1	0	-
<u>Eurycea quadridigitata</u>	3	0	-	0	0	-	0	0	-	0	0	-
<u>Bufo americanus</u>	0	0	-	0	0	-	0	0	X	0	0	-
<u>Bufo terrestris</u>	0	6	X	0	0	X	3	8	X	0	1	-
<u>Bufo woodhousei fowleri</u>	0	0	-	0	0	-	0	0	X	0	0	-
<u>Acris gryllus gryllus</u>	1	2	X	88	557	X	11	122	X	7	14	X
<u>Acris crepitans crepitans</u>	0	0	-	0	1	-	0	0	-	0	0	-
<u>Hyla crucifer</u>	0	0	X	0	0	X	0	4	X	0	0	-
<u>Hyla cinerea</u>	0	0	X	2	1	X	0	0	X	0	0	-
<u>Hyla squirrella</u>	0	0	-	0	0	-	0	0	X	0	0	-
<u>Limnaoedus ocularis</u>	0	0	-	0	0	X	0	0	X	0	0	-
<u>Rana catesbeiana</u>	1	3	X	0	1	X	1	0	X	1	0	-
<u>Rana virgatipes</u>	23	1	X	148	6	X	2	1	X	0	0	-
<u>Rana clamitans</u>	61	1	X	16	2	X	28	2	X	0	0	-
<u>Rana utricularia</u>	10	28	X	5	2	X	12	4	X	10	3	-
Unidentified <u>Hyla</u> sp.	0	0	-	0	0	-	0	2	-	0	0	-
Unidentified <u>Rana</u> sp.	4	0	-	2	0	-	6	0	-	0	0	-
Unidentified Anuran sp.	0	4	-	0	2	-	0	2	-	0	0	-

[1]Figure 8.2.1 X Indicates Call

Table 8.2.3 Observed water temperature means and ranges for larval and adult amphibians collected or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976

	Larvae					Adults				
		Mean		Range			Mean		Range	
Species	n	°C	°F	°C	°F	n	°C	°F	°C	°F
Siren intermedia	7	22.4	72	14.0-28.5	57-83	15	28.0	82	15.0-35.0	59-95
Necturus punctatus	9	18.1	64	12.5-28.0	54-82	10	24.3	76	18.2-32.0	65-90
Amphiuma means	0	-	-	-	-	3	20.7	69	20.5-21.0	69-70
Desmognathus fuscus	0	-	-	-	-	1	17.0	63	17.0	63
Stereochilus marginatus	2	6.0	43	6.0	43	0	-	-	-	-
Pseudotriton montanus	7	18.4	65	10.0-25.5	50-78	1	20.0	68	20.0	68
Pseudotriton ruber	10	18.0	64	17.0-22.0	63-72	0	-	-	-	-
Eurycea bislineata	298	18.4	65	5.5-29.0	42-84	4	19.8	68	17.0-25.5	63-78
Eurycea quadridigitata	3	12.0	54	12.0	54	0	-	-	-	-
Bufo americanus	0	-	-	-	-	0	-	-	-	-
Bufo terrestris	3	28.0	82	28.0	82	7	26.5	80	20.5-31.0	69-88
Bufo woodhousei fowleri	0	-	-	-	-	0	-	-	-	-
Acris gryllus gryllus	117	29.5	85	25.0-35.0	77-95	693	29.4	85	10.0-33.0	50-91
Acris crepitans crepitans	0	-	-	-	-	1	31.0	88	31.0	88
Hyla crucifer	0	-	-	-	-	4	8.0	46	8.0	46
Hyla cinerea	2	32.0	90	31.0-33.0	88-91	1	31.0	88	31.0	88
Hyla squirrella	0	-	-	-	-	0	-	-	-	-
Limnaoedus ocularis	0	-	-	-	-	0	-	-	-	-
Rana catesbeiana	2	16.5	62	6.0-27.0	43-81	2	22.0	72	20.5-23.5	69-74
Rana virgatipes	177	23.2	74	5.5-32.5	42-90	8	23.7	75	19.0-31.0	66-88
Rana clamitans	105	17.1	63	8.5-31.0	47-88	4	23.9	75	18.5-31.0	65-88
Rana utricularia	37	19.4	67	9.5-31.0	49-88	14	25.7	78	20.0-34.5	68-94
Unidentified Rana sp.	12	17.7	64	12.0-26.0	54-79	0	-	-	-	-

Table 8.2.4 Maximum thermal tolerance values for amphibian species collected or observed at Robinson Impoundment and Black Creek

Species	Adult Critical Thermal Maximum °C	°F	Adult Maximum Voluntary Temperature °C	°F	Larval Critical Thermal Maximum °C	°F	Maximum Temperature for Larval Development °C	°F	Maximum Embryonic Temperature Tolerance °C	°F
Siren intermedia										
Necturus punctatus										
Amphiuma means[1]	37.1[a]	99								
Desmognathus fuscus[2]	33.5[b]-36.2[a]	92-97								
Stereochilus marginatus										
Pseudotriton montanus										
Pseudotriton ruber	35.0[b]	95								
Eurycea bislineata	34.5[b]-34.6[a]	94	16.0[f]	61	34.5[c]	94				
Eurycea quadridigitata										
Bufo americanus	40.2[d]	104	32.3[f]	90	35.0[g]	95	31.0[i]	88		
Bufo terrestris			24.2[f]	76			35.0[i]	95		
Bufo woodhousei fowleri										
Acris gryllus										
Acris crepitans			34.8[f]	95						
Hyla crucifer			26.5[f]	80						
Hyla cinerea			33.4[f]	92			39.0[i]	102		
Hyla squirrella			25.0[f]	77						
Limnaoedus ocularis										
Rana catesbeiana	38.2[e]	101	30.0[f]-34.7[e]	86-95			35.0[j]	95	32.0[m]	90
Rana virgatipes										
Rana clamitans			29.0[f]	84					32.0[m]-35.0[n]	90-95
Rana utricularia[3]			34.7[f]	95	31.0-33.0[h]	88-91	33.0[j]-33.8[k]	91-93	28.0[m]	82

[1]Value reported for *Amphiuma means tridactylum*
[2]Values reported for *Desmognathus f. fuscus*
[3]Values reported for *Rana pipiens*
[a]Hutchinson (1961)
[b]Zweifel (1957)
[c]Brooks and Sassman (1965)
[d]Frost and Martin (1971)
[e]Lillywhite (1970)
[f]Brattstrom (1963)
[g]Volpe (1953)
[h]Atlas (1935)
[i]Ballinger & McKinney (1966)
[j]Lucas and Reynolds (1967)
[k]Zweifel (1968)
[m]Moore (1942)
[n]Moore (1939)

Table 8.2.5 Water temperatures recorded at larval amphibian sampling stations at Robinson Impoundment and Black Creek, July 1975 through May 1976

	1975												1976									
	July		Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.		March		April		May	
Station (Figure 8.2.1)	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
MHS-1 Creek	28	82	28	82	26.5	79	22.5	72	20	68	11.5	52	9	48	10	50	15.5	60	19.5	67	19	66
Swamp	22	72	26	79	23	73	19	66	20	68	9.5	49	5.5	42	6	43	11	52	15	59	17	63
MHS-2 Creek	28	82	29	84	29.5	85	23.5	74	21	70	12	54	10.5	51	12.5	54	16.5	64	20	68	23	73
Swamp	22	72	-	-	24	75	-	-	-	-	-	-	-	-	-	-	-	-	17	63	-	-
Stream	-	-	-	-	-	-	-	-	20.5	69	11.5	52	-	-	-	-	-	-	-	-	-	-
MHS-3 Creek	31	88	31	88	30.5	87	24.5	76	21	70	12.5	54	11	52	13	55	17.5	64	21	70	23.5	74
Stream	-	-	-	-	-	-	17	63	21	70	11	52	-	-	-	-	-	-	17	63	-	-
Puddle	-	-	-	-	-	-	-	-	-	-	-	-	9.5	49	13	55	12	54	17	63	19	66
MHS-4 Discharge Canal	39	102	41	106	39	102	34	93	21	70	13	55	24	75	25	77	28	82	30.5	87	34	93
Cove Surface	27	81	33	91	30	86	29	84	20	68	14	57	20	68	21.5	70	22	72	23	73	27	81
Cove Bottom	24	75	23	73	25	77	21.5	70	-	-	-	-	18	64	20.5	69	19	66	19	66	26	79
MHS-5 Cove	37	99	38	100	37	99	34	93	21	70	13	55	21	70	23	73	26	79	31	88	32	90
Stream Mouth	19	66	19	66	19	66	19	66	17	63	14	57	11	52	15	59	14.5	58	18.5	65	17	63
MHS-6 Lower Lagoon	29	84	33	91	34.5	94	26	79	18.5	65	11.5	52	10	50	10	50	14	57	26	79	22	72
Upper Lagoon	-	-	23.5	74	24	75	19	66	18	64	11	52	10	50	10	50	13	55	20	68	22	72
Stream Mouth	-	-	-	-	22	72	18	64	18	64	11	52	10	50	8	46	13	55	19.5	67	18	64
MHS-7 Cove	36	97	36.5	98	39	102	33	91	21.5	70	12.5	54	20	68	20.5	69	24.5	76	30	86	30	86
Stream Mouth	-	-	-	-	-	-	-	-	17	63	-	-	-	-	8.5	47	17	63	17	63	18	64
MHS-8 Cove	34	93	37	99	35	95	31	88	19.5	67	10	50	16	61	19.5	67	22	72	29	84	30	86
Beaver Pool	16.5	61	17	63	17.5	64	17	63	17.5	64	17	63	17.5	64	17	63	17	63	17	63	17	63
MHS-9 Cove	33.5	92	38	100	36	97	29.5	67	21.5	70	11	52	18	64	18	64	23.5	74	30	86	31	88
Stream	25	77	27	81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh	-	-	-	-	30.5	87	25	77	21.5	70	9	48	5	41	16	61	12.5	54	29	84	30	86
MHS-10 Impoundment	30.5	87	30	86	32	90	28	82	19	66	9	48	8	46	8	46	10	50	26.5	79	22	72
Lagoon	28	82	26	79	29	84	27	81	21	70	11	52	10.5	51	6	43	10	50	31	88	22	72
MHS-11 Lagoon	26	79	28	82	27	81	23.5	74	20	68	10	50	13	55	15.5	60	12.5	54	23	73	26	79
Stream Mouth	19.5	67	20.5	69	22	72	19.5	67	20	68	11	52	11.5	52	14	57	12.5	54	20	68	19	66
MHS-12 Shoreline	32.5	90	33	91	31	88	24	75	19	66	8.5	47	8.5	47	10.5	51	12.5	54	23.5	74	21	70
MHS-13 Cove	33	91	30.5	87	31	88	25	77	18	64	8	46	12.5	54	14	57	12	54	23	73	22	72

Table 8.2.6 Observed breeding seasons for eight anuran species found at Robinson Impoundment and Black Creek, June 1975 through May 1976 (Breeding calls were considered evidence of breeding season)

Species	Location (Figure 8.2.1)	1975 June	1975 July	1975 Aug	1975 Sept	1975 Oct	1975 Nov	1975 Dec	1976 Jan	1976 Feb	1976 Mar	1976 Apr	1976 May
Bufo terrestris	NF[1]	X[4]	X	X	X	X	X					X	X
	SF[2]	X	X	X	X	X	X					X	X
	BC[3]	X	X	X	X	X	X					X	X
Acris gryllus gryllus	NF	X	X	X	X							X	X
	SF	X	X	X								X	X
	BC		X										
Hyla crucifer	NF									X	X		
	SF									X	X		
	BC									X	X		
Hyla cinerea	NF	X	X	X									X
	SF	X	X	X									X
	BC	X	X	X									
Rana catesbeiana	NF	X											X
	SF	X	X		X							X	
	BC	X	X										
Rana virgatipes	NF		X	X								X	X
	SF		X	X								X	X
	BC											X	X
Rana clamitans	NF	X		X									X
	SF	X	X	X									X
	BC		X	X									
Rana utricularia	NF									X		X	X
	SF						X			X		X	X
	BC											X	X

[1]North of Transect F

[2]South of Transect F

[3]Black Creek South of Robinson Impoundment

[4]Indicates Months That Breeding Calls Were Heard

Table 8.3.1 Reptiles collected and/or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976 (Nomenclature follows Conant, 1975)

Scientific Name	Common Name
Aquatic and Semi-aquatic Species	
Chelydra serpentina	Snapping turtle
Sternotherus odoratus	Stinkpot
Clemmys guttata	Spotted turtle
Chrysemys scripta scripta	Yellow-bellied turtle
Chrysemys concinna concinna	River cooter
Chrysemys rubriventris	Red-bellied turtle
Deirochelys reticularia reticularia	Eastern chicken turtle
Natrix fasciata fasciata	Banded water snake
Natrix taxispilota	Brown water snake
Agkistrodon piscivorus piscivorus	Eastern cottonmouth
Terrestrial Species	
Terrapene carolina carolina	Eastern box turtle
Anolis carolinensis carolinensis	Green anole
Cnemidophorus sexlineatus sexlineatus	Six-lined racerunner
Eumeces fasciatus	Five-lined skink
Heterodon platyrhinos	Eastern hognose snake
Coluber constrictor	Black racer
Opheodrys aestivus	Rough green snake
Elaphe obsoleta obsoleta	Black rat snake
Lampropeltis getulus getulus	Eastern kingsnake
Leiolopisma laterale	Ground skink

Table 8.3.2 Number of aquatic reptiles collected and/or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976

Species	Black Creek		Impoundment[1]		
	Above Impoundment	Below Impoundment	North of Transect F	South of Transect F	Discharge Canal
Chelydra serpentina	0	4	0	0	0
Sternotherus odoratus	2	0	7	19	1
Clemmys guttata	0	2	5	0	0
Chrysemys s. scripta	0	6	48	22	12
Chrysemys c. concinna	0	0	0	1	0
Chrysemys rubriventris	0	0	0	1	0
Deirochelys r. reticularia	0	0	4	1	0
Unidentified turtles	0	1	40	13	0
Natrix f. fasciata	1	2	1	4	0
Natrix taxispilota	2	5	1	10	0
Unidentified *Natrix* sp.	2	4	3	3	0
Agkistrodon p. piscivorus	3	9	4	2	0

[1] Figure 8.2.1

Table 8.3.3 Critical thermal maxima (CTM) and maximum voluntary temperature (MVT) for aquatic reptilian species found at Robinson Impoundment and Black Creek

Species	Adult Critical Thermal Maximum (°C)				Adult Maximum Voluntary Temperature (°C)	
	Mean		Range			
	°C[1]	°F	°C[1]	°F	°C[2]	°F
Chelydra serpentina	39.46	103	37.4-40.6	99-105	24.5	76
Sternotherus odoratus	41.03	106	40.3-41.7	105-107	28.8	84
Clemmys guttata	41.98	107	41.2-42.5	106-109	-	-
Clemmys sp.[3]	-	-	-	-	27.0	81
Chrysemys scripta	41.00	106	40.2-42.0	104-108	-	-
Chrysemys concinna	41.80	107	40.4-42.8	105-109	-	-
Chrysemys rubriventria	39.36	103	38.4-39.9	101-104	-	-
Chrysemys sp.[4]	-	-	-	-	32.0	90
Deirochelys reticularia	41.30	106	40.8-42.2	105-108	25.6	78
Natrix f. fasciata	-	-	-	-	-	-
Natrix taxispilota	-	-	-	-	-	-
Natrix sp.[5]	-	-	-	-	29.5	85
Agkistrodon piscivorus	-	-	-	-	27.7	82

[1]Data from Hutchinson, et al. (1966)
[2]Data from Brattstrom (1965)
[3]Value reported for *Clemmys marmorata*
[4]Value reported for *Chrysemys picta*
[5]Value reported for *Natrix sipedon*

Table 8.4.1 Aquatic avifauna species by category observed at Robinson Impoundment, August 1974 through February 1976

Species	Species
Grebes	Red-necked grebe Horned grebe Pied-billed grebe
Surface-Feeding Ducks	Mallard Black duck Gadwall American wigeon Blue-winged teal Green-winged teal Wood duck
Diving Ducks	Redhead Ring-necked duck Lesser scaup Old squaw Bufflehead Ruddy duck Hooded merganser Red breasted merganser Common merganser
Herons and Bitterns	Great blue heron Green heron Little blue heron Great egret Snowy egret Yellow-crowned night heron Least bittern American bittern
Rails	King rail American coot
Shorebirds	Spotted sandpiper Killdeer Silitary sandpiper Northern phalarope Common snipe

Table 8.4.1 (continued)

Category	Species
Gulls and Terns	Herring gull
	Ring-billed gull
	Bonapartes gull
	Common tern
	Black tern
Miscellaneous	Common loon
	Canada goose
	Whistling swan
	Double crested cormorant
	Belted kingfisher

Table 8.4.2 Summary of aquatic avifauna quantitative observations in Robinson Impoundment, August 1974 through February 1976

Group	Number Observed	% of Total	% Observed Area I	% Observed Area II	% Observed Area III
Grebes	92	2	35	25	40
Surface-Feeding Ducks	516	14	1	11	88
Diving Ducks	544	15	71	21	8
Herons	30	1	17	33	50
Rails	2214	60	71	23	6
Shorebirds	59	2	49	42	9
Gulls	178	5	68	26	6
Miscellaneous*	71	2	34	23	43
TOTAL	3704	100	59	22	19

*Combined figures for Common loon
Canada goose
Whistling swan
Double-crested cormorant
Belted kingfisher

Table 8.4.3 Bird species observed at the Robinson Impoundment and Black Creek August 1974 through February 1976

Common Name	Scientific Name
Common loon	Gavia immer
Red-necked grebe	Podiceps grisegena
Horned grebe	Podiceps auritus
Pied-billed grebe	Podilymbus podiceps
Double-crested cormorant	Phalacrocorax auritus
Great blue heron	Ardea herodias
Green heron	Butorides virescens
Little blue heron	Florida caerula
Great egret	Casmerodius albus
Snowy egret	Leucophoyx thula
Black-crowned night heron	Nycticorax nycticorax
Yellow-crowned night heron	Nyctanassa violacea
Least bittern	Botarus lentiginosus
Whistling swan	Olor columbianus
Canada goose	Branta canadensis
Mallard	Anas platyrhynchos
Black duck	Anas rubripes
Gadwall	Anas strepera
Green-winged teal	Anas carolinensis
Blue-winged teal	Anas discors
American wigeon	Mareca americana
Wood duck	Aix sponsa
Redhead	Aythya americana
Lesser scaup	Aythya affinis
Ring-necked duck	Aythya collaris
Bufflehead	Bucephala albeola
Oldsquaw	Clangula hyemalis
Ruddy duck	Oxyura jamaicensis
Hooded merganser	Lophodytes cucullatus
Red-breasted merganser	Mergus serrator
Common merganser	Mergus merganser
Turkey vulture	Cathartes aura

Table 8.4.3 (continued)

Common Name	Scientific Name
Black vulture	Coragyps atratus
Sharp-shinned hawk	Accipiter striatus
Cooper's hawk	Accipiter cooperii
Red-tailed hawk	Buteo jamaicensis
Red-shouldered hawk	Buteo lineatus
Broad-winged hawk	Buteo platypterus
Marsh hawk	Circus cyaneus
Osprey	Pandion haliaetus
Pigeon hawk	Falco columbarius
Kestrel	Falco sparverius
Bobwhite	Colinus virginianus
King rail	Rallus elegans
American coot	Fulica americana
Killdeer	Charadrius vociferus
American woodcock	Philohela minor
Common snipe	Capella gallinago
Spotted sandpiper	Actitis macularia
Northern phalarope	Lobipes lobatus
Solitary sandpiper	Tringa solitaria
Herring gull	Larus argentatus
Ring-billed gull	Larus delawarensis
Bonaparte's gull	Larus philadelphia
Common tern	Sterna hirundo
Black tern	Childonias niger
Rock dove	Columba livia
Mourning dove	Zenaidura macroura
Yellow-billed cuckoo	Coccyzus americanus
Great horned owl	Bubo virginianus
Whip-poor-will	Caprimulgus vociferus
Chuck-will's-widow	Caprimulgus carolinensis
Common nighthawk	Chordeiles minor
Chimney swift	Chaetura pelagica
Ruby-throated hummingbird	Archilochus colubris
Belted kingfisher	Megaceryle aleyon
Yellow-shafted flicker	Colaptes auratus

Table 8.4.3 (continued) Page 3

Common Name	Scientific Name
Pileated woodpecker	Dryocopus pileatus
Red-bellied woodpecker	Centurus carolinus
Red-headed woodpecker	Melanerpes erythrocephalus
Hairy woodpecker*	Dendrocopos villosus
Downy woodpecker	Dendrocopos pubescens
Eastern kingbird	Tyrannus tyrannus
Least flycatcher	Empidonax minimus
Eastern wood pewee	Contopus virens
Tree swallow	Iridoprocne bicolor
Rough-winged swallow	Stelgidopteryx ruficollis
Barn swallow	Hirundo rustica
Cliff swallow	Petrochelidon pyrrhonota
Purple martin	Progne subis
Bank swallow	Riparia riparia
Blue jay	Cyanocitta cristata
Common crow	Corvus brachyrhynchos
Fish crow	Corvus ossifragus
Carolina chickadee	Parus carolinensis
Tufted titmouse	Parus bicolor
White-breasted nuthatch*	Sitta carolinensis
Brown-headed nuthatch	Sitta pusilla
Brown creeper*	Certhia familiaris
Winter wren	Troglodytes troglodytes
Carolina wren	Thryothorus ludovicianus
Mockingbird	Mimus polyglottos
Grey catbird	Dumetella carolinensis
Brown thrasher	Toxostoma rufum
Robin	Turdus migratorius
Hermit thrush	Hylocichla guttata
Veery	Hylocichla fuscescens
Eastern bluebird	Sialia sialis
Blue-gray gnatcatcher	Polioptila caerulea
Golden-crowned kinglet*	Regulus satrapa

Table 8.4.3 (continued) Page 4

Common Name	Scientific Name
Ruby-crowned kinglet	Regulus calendula
Cedar waxwing	Bombycilla cedrorum
Loggerhead shrike	Lanius ludovicianus
Starling	Sturnus vulgaris
White-eyed vireo	Vireo griseus
Solitary vireo	Vireo solitarius
Black and white warbler*	Mniotilta varia
Prothonatary warbler	Protonotaria citrea
Nashville warbler	Vermivora ruficapilla
Parula warbler	Parula americana
Myrtle warbler	Dendroica coronata
Pine warbler	Dendroica pinus
Yellowthroat	Geothlypis trichas
American redstart	Setophaga ruticilla
House sparrow	Passer domesticus
Eastern meadowlark	Sturnella magna
Red-winged blackbird	Agelaius phoeniceus
Orchard oriole	Icterus spurius
Rusty blackbird	Euphagus carolinus
Common grackle	Quiscalus quiscula
Brown-headed cowbird	Molothrus ater
Summer tanager	Piranga rubra
Cardinal	Richmondena cardinalis
Indigo bunting	Passer cyanea
American goldfinch	Spinus tristis
Rufous-sided towhee	Pipilo erythrophthalmus
Savannah sparrow	Passerculus sandwichensis
Vesper sparrow	Pooecetes gramineus
Slate-colored junco	Junco hyemalis
Field sparrow	Spizella pusilla
White-throated sparrow	Zonotrichia albicollis

Table 8.4.3 (continued)

Common Name	Scientific Name
Fox sparrow	*Passerella iliaca*
Swamp sparrow	*Melospiza georgiana*
Song sparrow	*Melospiza melodia*
Sharp-tailed sparrow	*Ammospiza caudacuta*

*Observed along Black Creek only.

Table 8.4.4 Bird species by month of observation and summary of quarterly surveys at Robinson Impoundment, August 1974 through February 1976

	August '74	September	November	February '75	April	May	June	July	August	September	October	November	December	January '76	February	Months Observed	Total Number Observed
Common loon	-	-	2 (1)	-	-	6 (2)	-	-	-	-	-	15 (14)	-	-	-	3	23
Red-necked grebe	-	-	4 (3)	5 (4)	x	-	-	-	-	-	-	-	-	-	-	2	9
Horned grebe	-	-	-	-	-	2 (2)	-	-	-	-	-	3 (2)	x	-	2 (2)	4	7
Pied-billed grebe	-	3 (2)	26 (8)	14 (5)	x	-	-	-	-	-	x	14 (5)	-	x	16 (8)	8	73
Double-crested cormorant	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	1	1
Great blue heron	-	2 (1)	3 (2)	6 (2)	x	2 (1)	x	-	1 (1)	x	x	1 (1)	x	x	4 (4)	13	19
Green heron	-	-	-	-	-	7 (3)	x	x	2 (2)	x	-	-	-	-	-	5	9
Little blue heron	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	-
Great egret	x	-	-	1 (1)	x	-	-	-	2 (1)	-	-	-	-	-	-	4	3
Snowy egret	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Yellow-crowned night heron	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
Least bittern	-	-	-	-	-	x	x	-	x	-	-	-	-	-	-	3	-
American bittern	-	1 (1)	-	-	x	-	-	-	1 (1)	-	-	-	-	-	-	3	2
Whistling swan	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	1	-
Canada goose	-	-	-	12 (3)	x	-	-	-	-	-	-	x	-	x	-	4	12
Mallard	x	5 (3)	5 (5)	14 (5)	x	11 (7)	x	-	1 (1)	x	-	25 (25)	x	x	2 (2)	13	63
Black duck	-	-	2 (1)	-	-	-	-	-	-	-	-	x	-	-	2 (2)	3	4
Gadwall	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	1	-
Green-winged teal	-	-	2 (2)	-	x	-	-	-	-	-	-	-	-	-	-	2	2
Blue-winged teal	-	1 (1)	7 (7)	1 (1)	x	-	-	-	-	x	x	-	-	-	2 (2)	7	11
American wigeon	-	-	2 (2)	12 (6)	x	-	-	-	-	-	-	5 (5)	-	-	x	5	19
Wood duck	x	147 (62)	6 (6)	6 (2)	x	17 (14)	x	x	86 (48)	x	-	27 (12)	x	-	7 (6)	13	296
Redhead	-	-	-	-	-	-	-	-	-	-	-	3 (3)	-	-	2 (2)	2	5
Ring-necked duck	-	-	15 (11)	-	-	-	-	-	-	-	-	222 (184)	x	-	33 (16)	4	270
Lesser scaup	-	-	x	-	x	-	-	-	-	-	-	-	-	-	4 (2)	3	4
Bufflehead	-	-	11 (5)	3 (2)	-	-	-	-	-	-	-	x	-	x	33 (14)	5	47
Ruddy duck	-	-	63+ (35+)	x	-	-	-	-	-	-	-	2 (1)	-	x	129 (77)	5	194
Hooded merganser	-	-	x	-	x	-	-	-	-	-	-	-	-	-	4 (4)	3	4
Red-breasted merganser	-	-	1 (1)	-	-	3 (2)	-	-	-	-	-	-	-	-	1 (1)	3	5
Turkey vulture	x	3 (3)	4 (4)	x	x	1 (1)	x	x	3 (3)	x	x	x	-	x	5 (3)	14	16
Black vulture	-	-	-	x	-	-	-	-	-	-	-	-	-	-	3 (3)	2	3
Sharp-shinned hawk	-	1 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Cooper's hawk	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Red-tailed hawk	-	1 (1)	-	2 (1)	x	-	x	x	-	-	x	2 (1)	x	-	-	8	5
Red-shouldered hawk	x	1 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Broad winged hawk	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-	2	-
Marsh hawk	-	x	-	x	-	1 (1)	-	-	-	-	-	2 (1)	x	x	1 (1)	7	4
Osprey	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	2	-
Kestrel	-	-	2 (2)	x	-	-	-	-	-	-	x	3 (1)	x	-	1 (1)	6	6
Bobwhite	x	1 (1)	1 (1)	2 (2)	-	2 (2)	x	x	1 (1)	x	x	-	-	-	-	10	7
King rail	x	2 (2)	5 (3)	x	x	x	x	-	3 (2)	-	-	-	-	-	-	8	10
American coot	-	-	339+ (119+)	272 (85)	x	3 (1)	-	-	1 (1)	-	x	1394 (587)	x	x	174 (58)	10	2,183
Killdeer	-	-	-	2 (2)	-	-	-	-	-	-	-	2 (2)	-	-	1 (1)	3	5
American woodcock	-	-	-	-	-	x	-	-	-	-	-	-	x	-	-	2	-
Spotted sandpiper	-	7 (3)	-	-	-	30 (13)	x	-	19 (8)	-	-	-	-	-	-	4	56
Northern phalarope	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	1	1
Solitary sandpiper	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
Herring gull	-	-	4 (3)	-	-	x	-	-	-	-	-	1 (1)	-	-	2 (2)	4	7
Ring billed gull	-	-	117 (38)	7 (4)	x	7 (6)	x	-	x	-	-	5 (4)	x	x	6 (2)	10	142
Bonapartes gull	x	-	24 (12)	-	-	x	-	-	-	-	-	-	-	-	-	3	24
Common tern	x	1 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Black tern	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Rock dove	-	-	-	4 (4)	-	4 (4)	x	-	-	-	x	-	-	-	7 ([illegible])	5	15
Mourning dove	x	17 (14)	5 (3)	30 (9)	x	35 (13)	x	x	191 (110)	-	x	23 (22)	x	x	28 (7)	14	329
Yellow-billed cuckoo	-	-	-	-	-	x	-	-	1 (1)	-	x	x	-	-	-	4	1
Great horned owl	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
Whip-poor-will	-	-	-	-	-	2 (2)	x	x	-	-	-	-	-	-	-	3	2
Chuck-will's widow	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	2	-
Common nighthawk	-	-	-	-	-	1 (1)	-	-	2 (2)	x	-	-	-	-	-	3	3
Chimney swift	-	18 (15)	-	-	x	2 (2)	x	-	7 (6)	x	-	-	-	-	-	6	27
Belted kingfisher	x	11 (8)	6 (3)	2 (2)	-	3 (2)	-	-	6 (4)	x	x	7 (4)	x	x	2 (2)	12	37
Yellow-shafted flicker	-	35 (21)	5 (3)	19 (7)	-	4 (2)	x	x	1 (1)	x	x	15 (8)	x	x	6 (2)	13	85
Pileated woodpecker	-	4 (2)	2 (1)	2 (1)	-	7 (3)	x	-	1 (1)	x	x	-	-	x	1 (1)	9	17
Red-bellied woodpecker	-	-	-	-	-	-	-	-	-	-	x	1 (1)	-	x	2 (1)	4	3
Red-headed woodpecker	-	x	-	x	x	-	-	-	-	-	-	-	-	-	-	3	-
Eastern kingbird	x	-	-	-	-	28 (13)	x	x	55 (27)	x	-	-	-	-	-	6	83

Table 8.4.4 (continued)

Least flycatcher	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	1	1
Eastern wood pewee	-	-	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	1	1
Tree swallow	-	-	-	-	-	11 (4)	-	-	-	x	-	-	-	-	-	2	11
Rough-winged swallow	x	16 (10)	-	-	x	7 (4)	x	x	47 (46)	x	-	-	-	-	-	8	70
Barn swallow	-	-	-	-	-	22 (11)	x	x	8 (4)	-	-	-	-	-	-	4	30
Cliff swallow	-	26 (21)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	26
Purple martin	-	-	-	-	-	19 (14)	x	x	599 (356)	-	-	-	-	-	-	4	618
Bank swallow	-	11 (11)	-	-	-	-	x	-	-	-	-	-	-	-	-	2	11
Bluejay	x	101 (47)	14 (6)	83 (54)	x	22 (7)	x	x	26 (8)	x	x	6 (3)	-	x	8 (4)	14	260
Common crow	x	9 (5)	-	2 (1)	x	27 (13)	x	x	15 (11)	x	x	10 (10)	-	x	-	12	63
Fish crow	x	1 (1)	-	x	x	9 (6)	x	x	3 (3)	-	x	-	-	-	-	9	13
Carolina chickadee	-	2 (1)	7 (7)	2 (2)	x	-	-	-	2 (2)	-	-	1 (1)	x	x	7 (3)	9	21
Brown-headed nuthatch	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	1
Carolina wren	-	1 (1)	1 (1)	2 (1)	-	3 (3)	x	-	1 (1)	-	x	1 (1)	x	x	2 (2)	11	11
Mockingbird	-	7 (5)	-	6 (3)	x	7 (4)	x	x	13 (6)	x	x	3 (1)	x	x	1 (1)	13	37
Catbird	-	7 (3)	-	1 (1)	-	8 (4)	-	x	9 (4)	x	x	1 (1)	-	x	2 (2)	10	28
Bluebird	-	-	-	-	-	-	-	-	-	-	-	6 (6)	-	-	x	2	6
Brown thrasher	-	-	-	-	-	3 (2)	-	x	-	x	-	-	x	-	-	4	3
Robin	-	-	1 (1)	44 (28)	-	14 (7)	x	-	11 (7)	-	-	14 (12)	x	-	3 (2)	8	87
Hermit thrush	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	-	-	1	1
Veery	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	-
Blue-gray gnatcatcher	-	-	-	-	x	5 (4)	x	-	3 (3)	-	-	-	-	-	-	4	8
Ruby-crowned kinglet	-	-	-	9 (4)	x	-	-	-	-	-	-	3 (1)	x	x	15 (15)	6	27
Cedar waxwing	-	-	-	34 (30)	-	-	-	-	-	-	-	-	-	x	-	2	34
Loggerhead shrike	-	-	1 (1)	x	x	x	x	x	-	-	x	1 (1)	-	x	-	9	2
Starling	-	79 (62)	22 (16)	59 (38)	x	36 (28)	x	-	22 (22)	-	-	6 (3)	x	-	6 (5)	10	230
White-eyed vireo	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	2	-
Solitary vireo	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	1	-
Prothonotary warbler	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
Nashville warbler	-	-	-	-	-	1 (1)	-	-	1 (1)	x	x	-	-	-	-	4	2
Parula warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myrtle warbler	-	-	-	2 (1)	x	-	-	-	-	-	-	-	x	x	5 (4)	5	7
Pine warbler	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	-
Yellow throat	-	-	-	-	-	8 (4)	x	x	3 (2)	x	-	-	-	x	-	6	11
American redstart	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
House sparrow	-	-	-	1 (1)	-	-	-	-	-	-	-	-	-	-	-	1	1
Eastern meadowlark	-	3 (3)	35+ (35+)	2 (2)	x	2 (1)	x	-	-	-	-	1 (1)	x	x	19 (13)	10	62
Red-winged blackbird	-	137 (96)	539+ (246+)	462+ (195+)	x	381+ (115+)	x	x	78 (40)	x	x	2069 (1068)	x	x	87 (65)	14	3,753
Orchard oriole	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	-
Rusty blackbird	-	-	26 (23)	-	-	-	-	-	-	-	-	-	-	-	-	1	26
Common grackle	-	82 (74)	4 (3)	45 (23)	x	167 (50)	x	x	74 (53)	-	-	44 (40)	-	-	29 (19)	10	445
Brown-headed cowbird	-	1 (1)	-	-	-	3 (3)	-	-	-	-	-	-	-	-	-	2	4
Summer tanager	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	-
Cardinal	-	1 (1)	-	7 (4)	x	7 (3)	x	-	2 (2)	-	x	1 (1)	x	x	2 (1)	11	20
Indigo bunting	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	-
American goldfinch	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	2	-
Rufous-sided towhee	-	4 (3)	4 (2)	12 (5)	x	8 (5)	x	x	16 (5)	x	-	4 (2)	x	x	10 (6)	13	58
Savannah sparrow	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	-
Vesper sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	1	-
Slate-colored junco	-	-	-	3 (3)	-	-	-	-	-	-	-	2 (2)	-	x	-	3	5
Field sparrow	-	-	2 (1)	1 (1)	x	-	x	-	-	-	-	-	x	-	1 (1)	7	4
Fox sparrow	-	-	1 (1)	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Swamp sparrow	-	-	4 (3)	23 (7)	-	-	-	-	-	-	-	x	-	-	-	3	27
Song sparrow	-	-	2 (2)	-	-	-	-	-	-	-	-	31 (13)	x	-	5 (3)	4	38
Sharp-tailed sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	1	-
Tufted titmouse	-	-	-	-	-	x	-	-	1 (1)	-	-	-	-	-	-	2	1
Ruby throated hummingbird	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	1	-
Downy woodpecker	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1	-
White throated sparrow	-	-	-	-	-	-	-	-	-	-	-	5 (5)	x	x	3 (3)	4	8
Common merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 (1)	1	2
Oldsquaw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8 (4)	1	8
Common snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 (1)	1	2
TOTAL SPECIES OBSERVED	19	38	43	50	45	67	42	23	45	25	25	46	28	37	51		
TOTAL NUMBERS OBSERVED	-	749	1326+	1217+	-	953	-	-	1318	-	-	3974	-	-	697		10,234

*First figure indicates total number observed for all four surveys. Number in parenthesis is the maximum number observed during any one survey.

Table 8.4.3 Bird species by month of observation and summary of quarterly survey at Black Creek September 1974 through February 1976

Species	September '74		November		February '75		May			June			July			August			September			October			November			December			January '76			February			Total Number Observed		
	H	K	H	K	H	K	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L
Black vulture	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Bobwhite (call)	-	-	-	-	-	-	-	1	1	-	-	-	-	-	x	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Mourning dove	3	-	2	-	-	-	-	1	x	-	-	-	x	x	x	2	-	1	-	-	x	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	8	2	1
Chimney swift	-	-	-	-	-	-	-	-	4	-	-	-	-	-	x	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
Belted kingfisher	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	x	-	1	1	-	-	-	-	-	-	1	-	-	3	1	1
Yellow-shafted flicker	-	-	4	-	1	-	-	x	2	-	-	-	-	-	x	-	-	1	-	-	x	x	-	x	2	1	2	x	-	x	-	-	-	-	-	-	7	1	5
Pileated woodpecker	-	-	-	-	-	-	-	4	1	-	x	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	1	5	1
Red headed woodpecker	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Downy woodpecker	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	1	-	-	-	x	-	-	-	-	-	-	-	3
Bluejay	1	1	2	-	2	2	-	1	1	-	-	-	-	-	x	1	-	x	x	x	x	x	x	x	1	-	1	-	-	-	-	-	-	-	-	-	5	4	2
Common crow	-	1	-	-	-	-	-	5	x	-	-	-	-	-	-	2	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	-
Fish crow	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
Carolina chickadee	-	6	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	15	2	5	-	-	x	x	x	x	1	2	-	19	12	5
Tufted titmouse	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	1	-	-	x	x	x	-	-	5	-	-	6	1	-
White breasted nuthatch	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Winter wren	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Carolina wren	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	5	1	-	x	x	x	-	-	1	-	-	1	6	1
Gray catbird	-	1	-	1	-	x	-	-	-	-	-	-	-	-	-	1	-	1	-	-	x	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	1	2	1
Veery	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Blue gray gnatcatcher	-	-	-	-	-	-	1	5	8	x	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	8
Golden crowned kinglet	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	2	-
Ruby crowned kinglet	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	3	-	-	9	4	-
Loggerhead shrike	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Starling	3	-	16	2	5	-	3	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	27	2	-
Prothonotary warbler	-	-	-	-	-	-	1	1	2	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
Parula warbler	-	-	-	-	-	-	-	2	5	-	x	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	6
Yellowthroat	-	-	-	-	-	-	-	-	1	-	-	x	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	2
Red-winged blackbird	17	-	3	-	-	-	-	-	-	-	-	-	x	-	-	3	-	-	-	-	-	x	-	-	2	13	2	-	-	-	-	-	-	-	-	-	25	13	2
Common grackle	2	-	-	-	-	2	1	2	10	-	-	-	-	-	x	-	1	3	x	-	-	-	x	-	-	42	20	-	-	-	-	-	-	-	25	-	3	72	33
Cardinal	1	-	-	2	-	-	4	1	2	x	-	x	-	-	x	1	-	-	-	-	x	x	-	-	1	2	-	x	-	-	-	-	-	2	-	-	9	5	2
Rufous-sided towhee	-	-	-	3	1	1	-	-	-	-	-	-	-	-	-	2	-	x	-	-	x	x	-	x	1	-	-	-	x	-	-	-	-	-	-	-	4	4	-
Savannah sparrow	-	-	-	2	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
White throated sparrow	-	-	-	2	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	-	2	-
Song sparrow	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3	-	1
Wood duck	-	-	-	-	-	-	-	x	x	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Spotted sandpiper	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hairy woodpecker	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	1	-	1
Eastern kingbird	-	-	-	-	-	-	-	x	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Purple martin	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigo bunting	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mockingbird	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	x	-	-	-	x	-	-	2	-	1	-	-	-	-	x	-	-	-	-	2	-	1
Black and white warbler	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whip-poor-will	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eastern bluebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	3	-	-	x	-	-	-	-	-	-	-	-	3
Barn swallow	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American bittern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Yellow-billed cuckoo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Red-tailed hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	2	-	-
Robin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	1	5	-	1	32
Eastern meadowlark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-bellied woodpecker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	x	x	-	-	1	-	-	2	1	-
Cedar waxwing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	6	-	-	x	-	-	-	-	-	-	-	8	6
Myrtle warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	11	-	1	11	-	26
House sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Slate colored junco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
American goldfinch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Brown creeper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Brown thrasher	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Hermit thrush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	1	-	-	1	-
Rusty blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Broad-winged hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-
Pigeon hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Brown-headed nuthatch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
	H	K	H	K	H	K	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L	H	K	L
Total Number of Species Observed	7	5	7	8	6	8	14	15	18	2	4	4	6	3	10	10	3	11	3	1	6	8	6	8	12	10	16	3	3	10	8	5	3	9	9	5			
Total Number Seen (Quarterly only)	28	10	31	15	13	10	17	24	41	-	-	-	-	-	-	15	3	17	-	-	-	-	-	-	35	76	98	-	-	-	-	-	-	26	35	9	164	173	165

Table 8.5.1 Mammal species observed at Robinson Impoundment and Black Creek, August 1974 through February 1976

Opossum (Didelphis marsupialis)

Starnose mole (Condylura cristata)

Eastern cottontail (Sylvilagus floridanus)

Gray squirrel (Sciurus carolinensis)

Beaver (Castor canadensis)

Cotton rat (Sigmodon hispidus)

Muskrat (Ondatra zibethica)

Norway rat (Rattus norvegicus)

Red fox (Vulpes fulva)

Grey fox (Urocyon cinereoargentus)

Raccoon (Procyon lotor)

Mink (Mustela vison)

Striped Skunk (Mephitis mephitis)

Otter (Lutra canadensis)

Whitetail deer (Odocoileus virginianus)

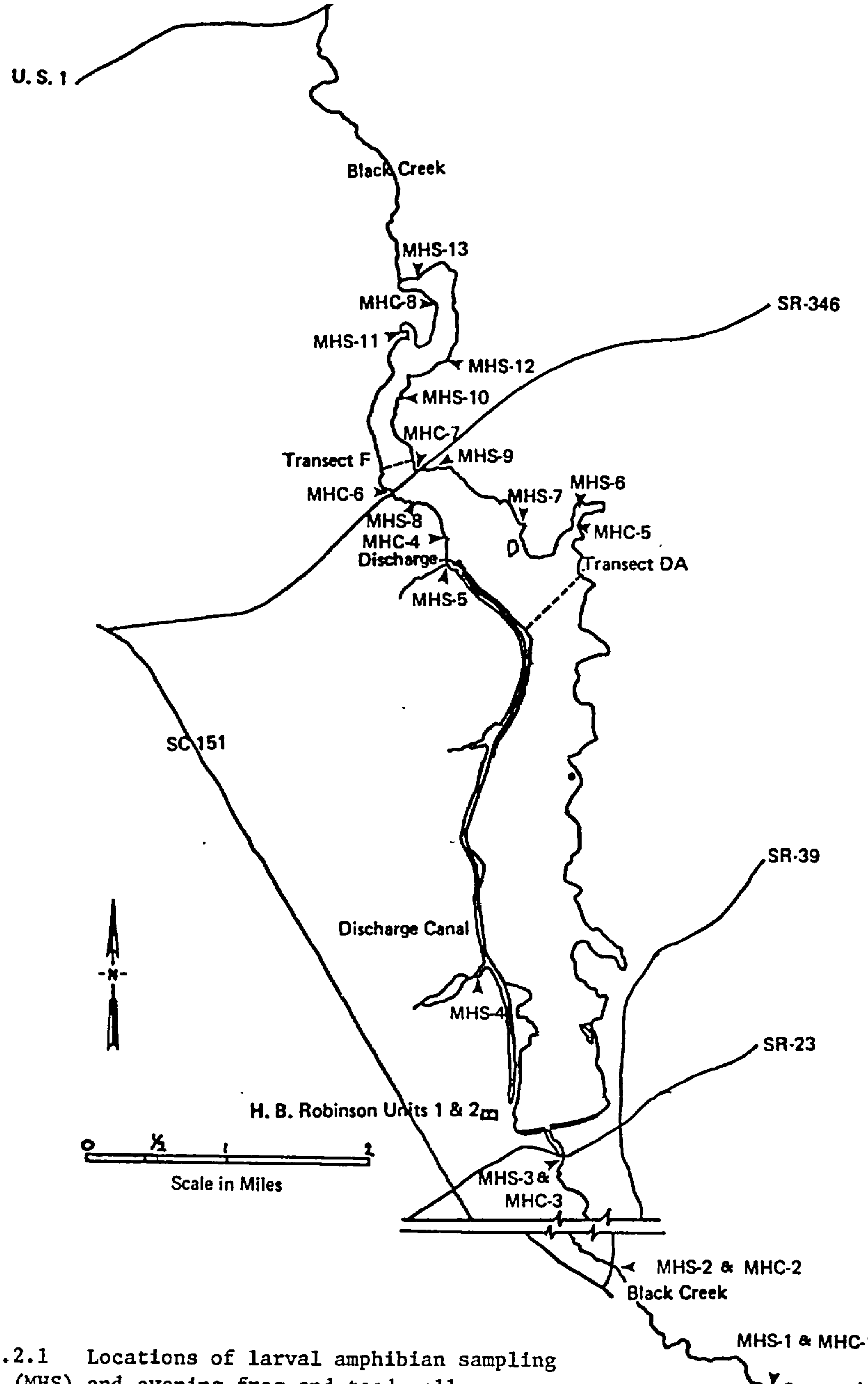
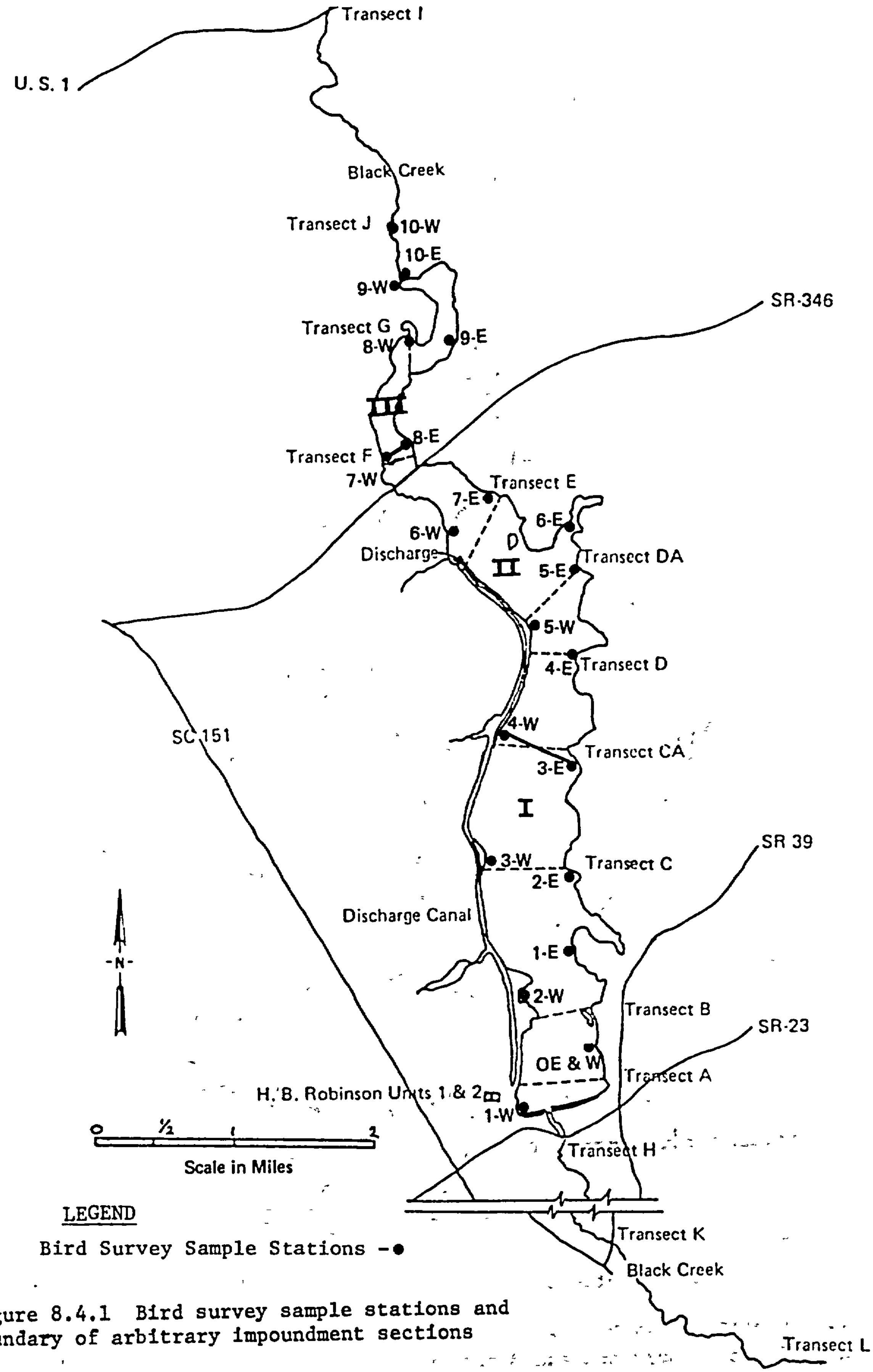


Figure 8.2.1 Locations of larval amphibian sampling stations (MHS) and evening frog and toad call survey stations (MHC)



LEGEND

Bird Survey Sample Stations -●

Figure 8.4.1 Bird survey sample stations and boundary of arbitrary impoundment sections

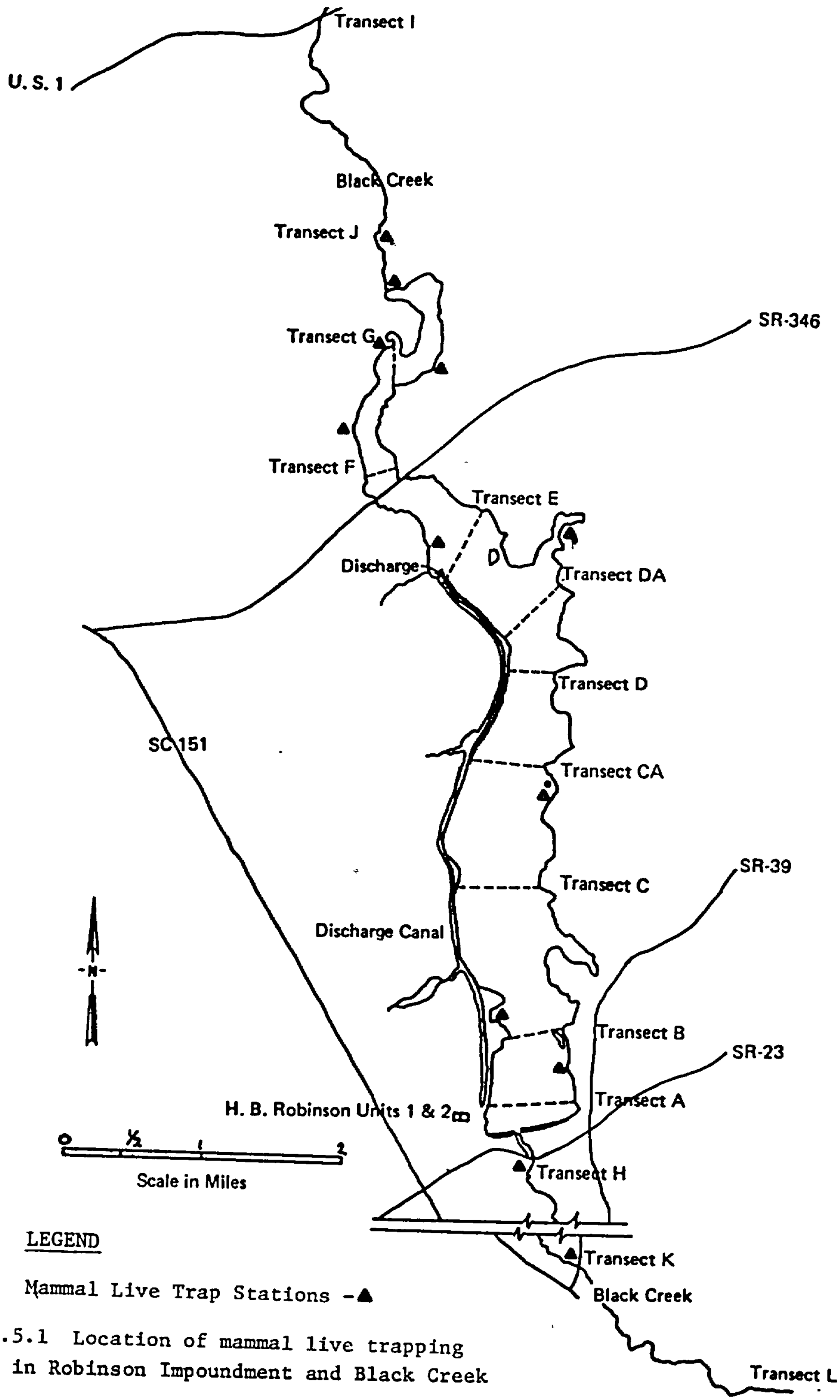


Figure 8.5.1 Location of mammal live trapping stations in Robinson Impoundment and Black Creek

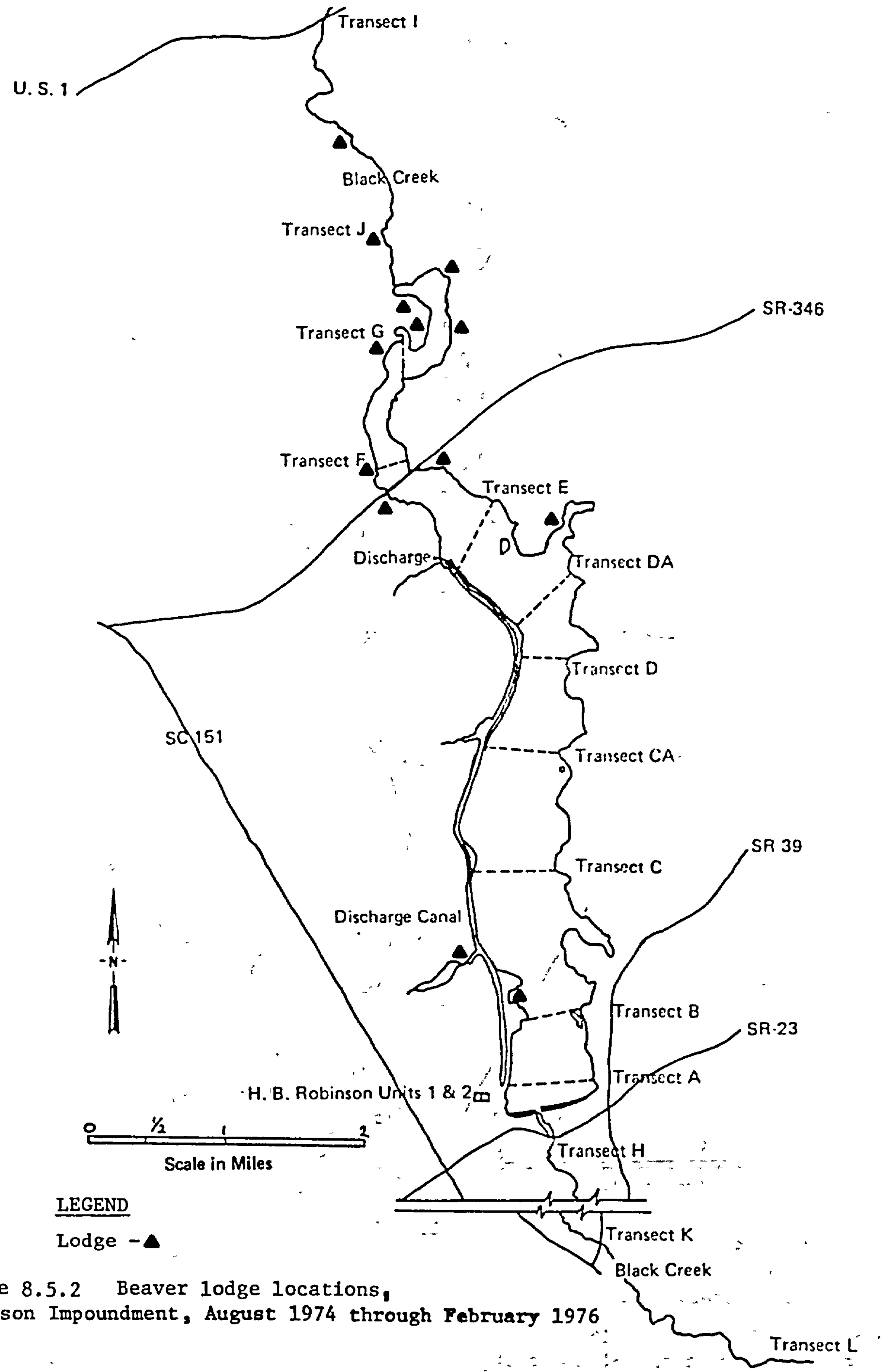


Figure 8.5.2 Beaver lodge locations, Robinson Impoundment, August 1974 through February 1976

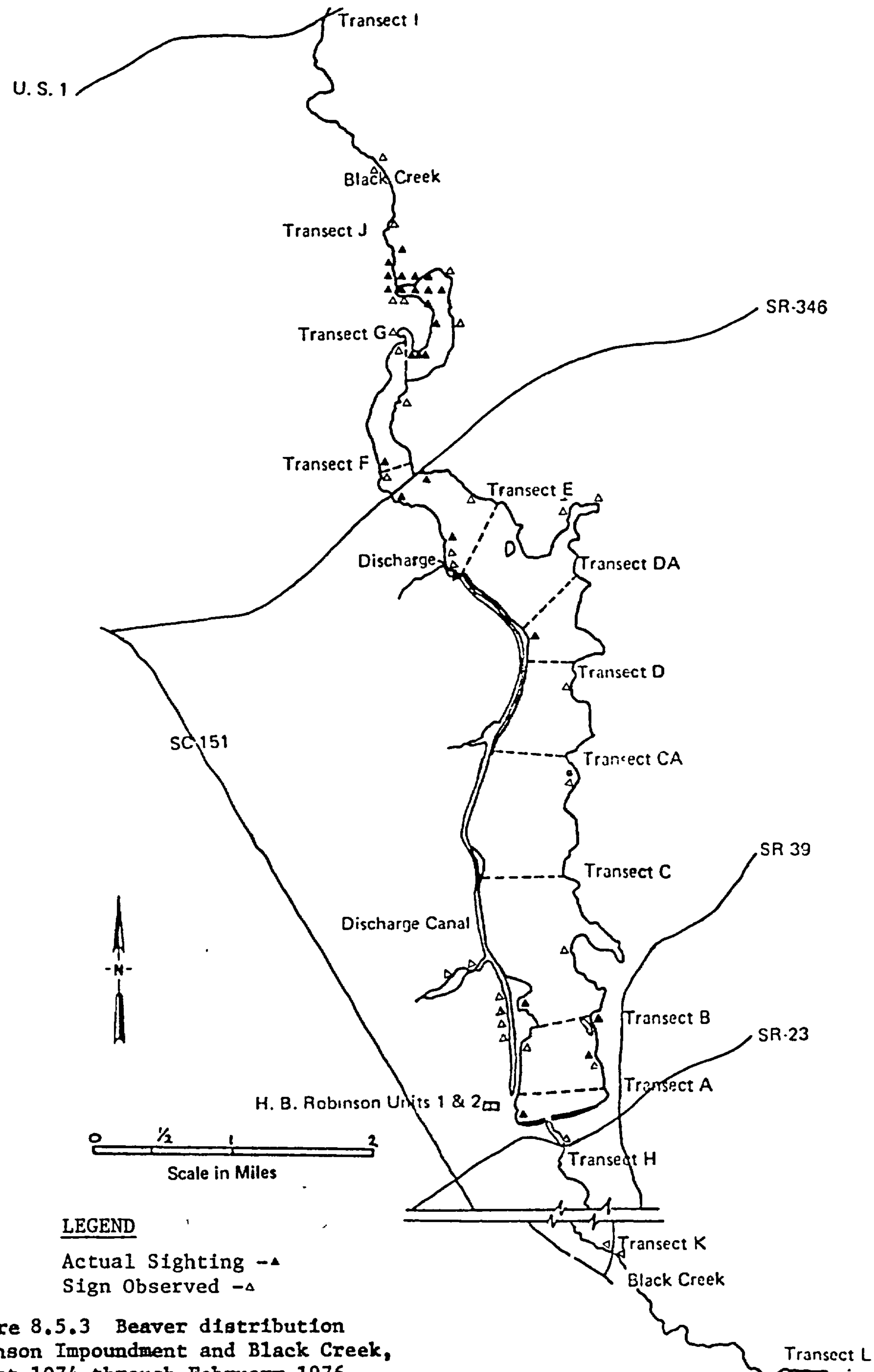
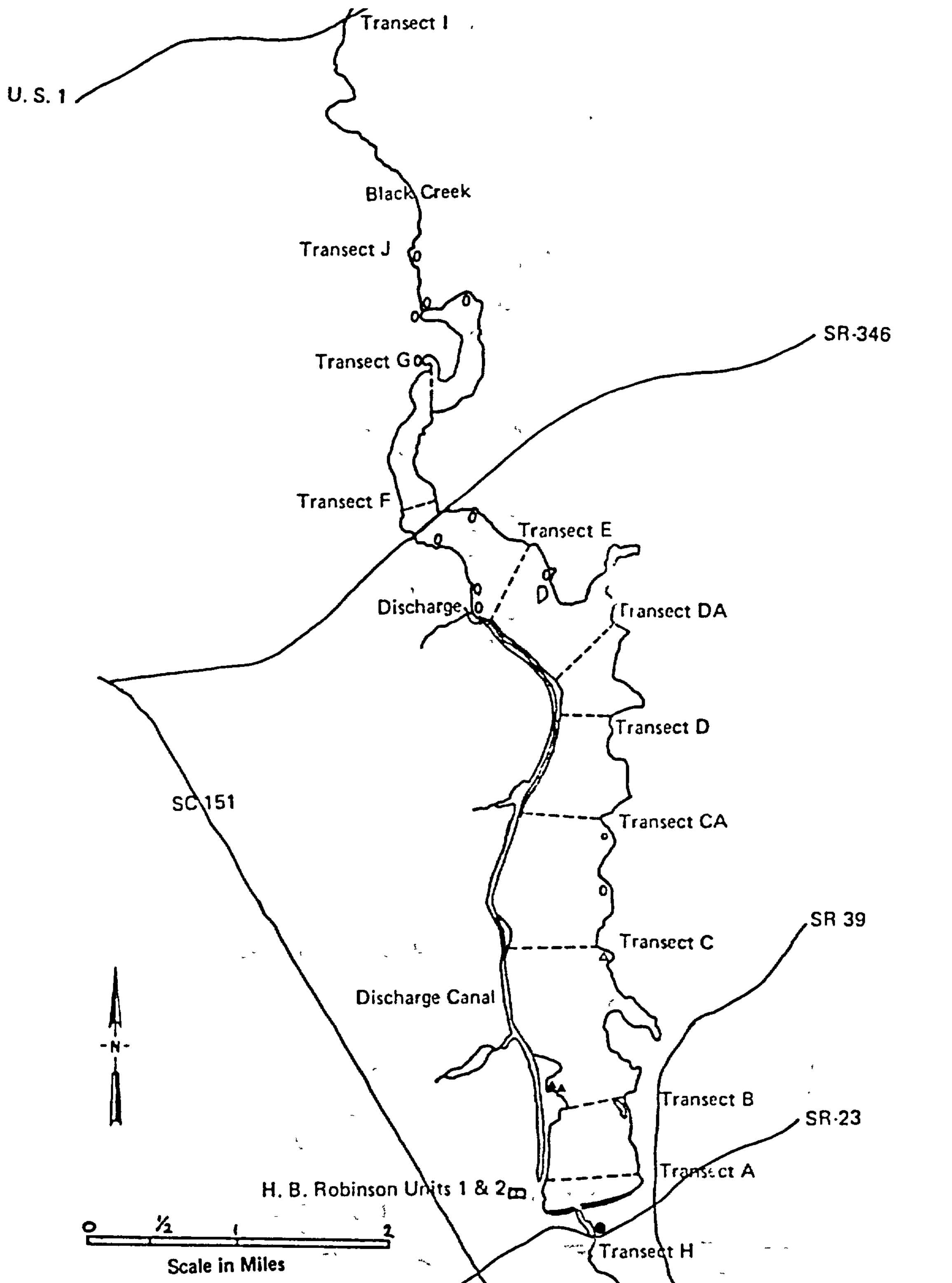


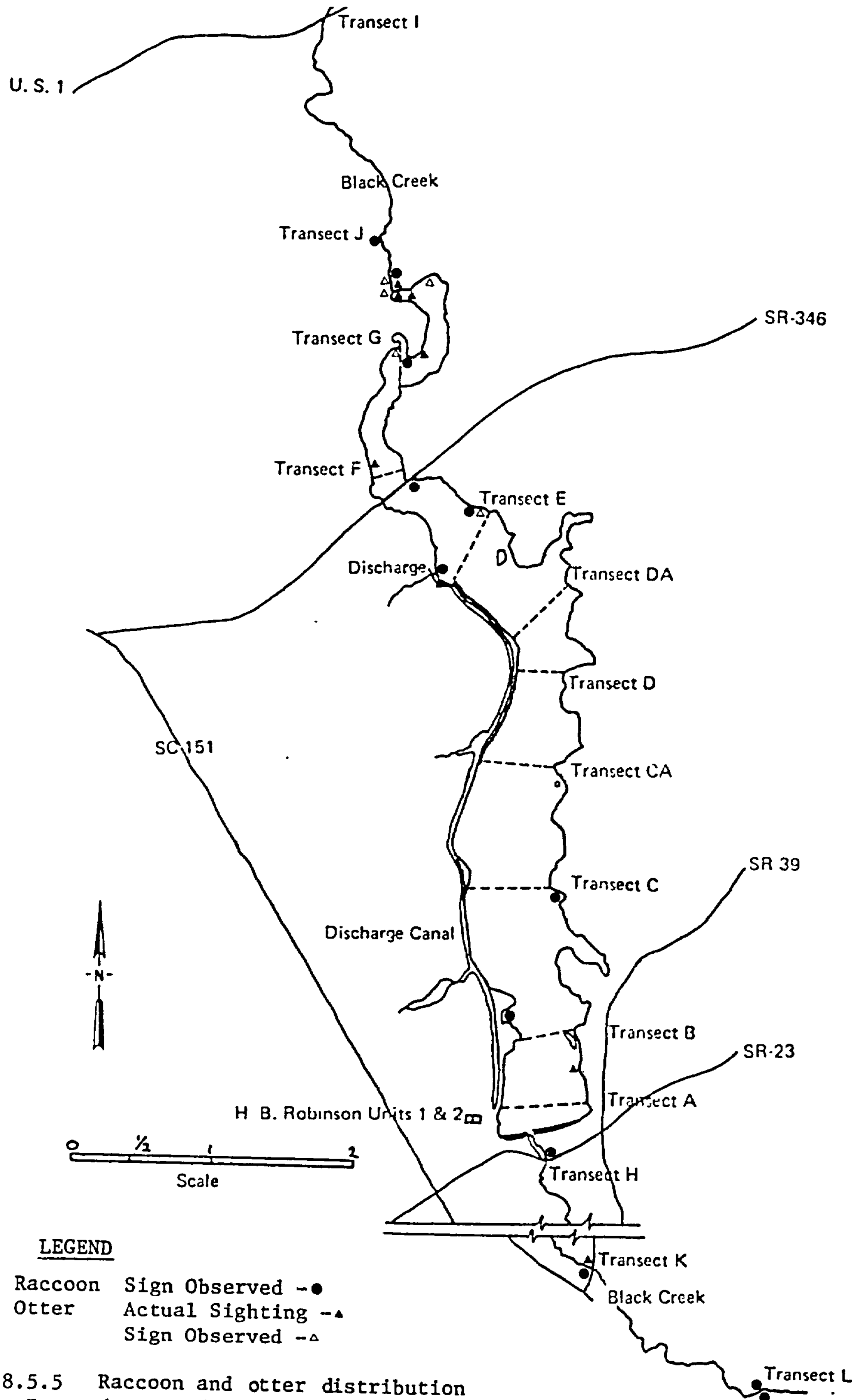
Figure 8.5.3 Beaver distribution Robinson Impoundment and Black Creek, August 1974 through February 1976



LEGENDS

Mink Actual Sighting -▲
Sign Observed -△
Muskrat Actual Sighting -●
Sign Observed - o

Figure 8.5.4 Muskrat and mink distribution Robinson Impoundment and Black Creek, August 1974 through February 1976



LEGEND

Raccoon Sign Observed -●
Otter Actual Sighting -▲
Sign Observed -△

Figure 8.5.5 Raccoon and otter distribution Robinson Impoundment and Black Creek, August 1974 through February 1976